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CAMBRIAN GEOLOGY AND PALEONTOLOGY

No. 2.—CAMBRIAN TRILOBITES

WITH SIX PLATES

BY

CHARLES D. WALCOTT

No. 1805

CITY OF WASHINGTON

PUBLISHED BY THE SMITHSONIAN INSTITUTION

April 25, 1908

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(With Six Plates)

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The monograph on the Cambrian Brachiopoda,[1] upon which I have been working for so long, is about ready for the press, and attention is now being given to the preliminary study of some of the American Cambrian trilobites. If students and collectors in any country know of interesting or new forms of Cambrian or Lower Ordovician trilobites, or of more perfect specimens representing previously described forms, I should very much like to have their coöperation in making this investigation as thorough and complete as possible.

This is the first of a series of brief papers that will be published as new material of interest is worked up. The classification of Dr. Charles E. Beecher[2] will be followed, in the preliminary studies at least, with such modifications as may appear necessary during the course of the investigations.

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[1] To be published as Monograph LI of the U. S. Geological Survey.

[2] American Jour. Sci., 4th ser., vol. III, 1897, pp. 89–106, 181–207.

Order PROPARIA Beecher

BURLINGIDÆ, new family

Dorsal shield small, elongate, broad oval in outline. Cephalon about one-fourth the length, transversely semicircular; genal angle acute or spinose; glabella with transverse lobes. Free cheeks small, separate. Facial sutures cut the margin in front of the genal angles, extend in to the posterior portion of the eye lobe and outward from the anterior portion to the antero-lateral margin of the cephalon. Eyes of medium size, clearly defined.

Thorax with fourteen segments in the one species preserving them; pleuræ with flat, straight furrows.

Pygidium large, with strong axis and pleural lobes, or small and with medium axis and pleural lobes.

STRATIGRAPHIC RANGE.—Central portion of the Middle Cambrian to the *Agnostus pisiformis* zone of the Swedish Upper Cambrian.

OBSERVATIONS.—This family includes the genera *Burlingia* and *Schmalenseeia*.[1] The first is represented by entire specimens and the latter by the cephalon, fragments of the thorax, and entire pygidia. The facial sutures and free cheeks relate *Burlingia* to some forms of the Cheiruridæ, while the pygidium of *Burlingia* recalls the simple pygidium of *Paradoxides*, and the pygidium of *Schmalenseeia* recalls that of *Amphion*. The flat, straight furrowed pleuræ of the thorax of *Burlingia* recall the pleuræ of *Olenoides*. The assemblage of characters in *Burlingia* and *Schmalenseeia* clearly indicate a distinct family of the Proparia, more primitive than any other forms of that order.

BURLINGIA, new genus

Dorsal shield small, elongate, broadly oval. Cephalon semicircular; one-fourth the length of the entire shield; genal angles with spines; cranidium[2] with anterior and posterior limbs that extend outward from the glabella to the outer margin; glabella slightly convex, with indications of lobes. Free cheeks subquadrangular, small. Facial sutures extend from in front of the genal angles inward to the eyes and then obliquely outward and forward, cutting the antero-lateral margin. Eyes of medium size.

Thorax with fourteen segments; pleuræ with a flat, direct furrow; pleuræ extended into backward-curving, falcate extremities.

---

[1] Moberg, 1903, Meddelande från Lunds Geol, Mineral. Inst. No. 5 (Geol. Fören. i Stockholm Förhandlingar, Bd. xxv, Häft 2, 1903, No. 219), p. 96.

[2] The cranidium includes all portions of the cephalon except the free cheeks and eye lobes.

Pygidium small, elongate, without defined segments.

GENOTYPE.—*Burlingia hectori,* new species.

OBSERVATIONS.—This genus is represented by a single species from the central portion of the Middle Cambrian fauna. The only form with which it can be directly compared is *Schmalenseeia* Moberg,[1] which is represented by specimens of the cranidium, pygidium, and fragments of the thoracic segments belonging to a single species. The cranidium of *Schmalenseeia* differs in having a convex glabella divided into four lobes by four transverse furrows, and in the presence of a defined occipital segment. The fragments of the thorax illustrated by Dr. Moberg (1903, pl. IV) and his description of them indicate that the pleuræ were flattened and marked by shallow, direct furrows similar to those on the pleuræ of *Burlingia.* With the present information, it is in the pygidium that the great difference in the two genera is found. The pygidium of *Schmalenseeia* is large and it has a strong axial lobe divided into a number of segments; the pleural lobes are broad and marked by numerous backward-curving, flat furrows much like those of the thoracic segments of *Burlingia.* The pygidium of *Burlingia* is small and apparently without segments or pleural lobes; it is a simple plate as in *Paradoxides.*

Dr. Moberg (1903, p. 100) has noted the resemblance between the direction of the facial sutures of *Schmalenseeia* and those of some genera of the Cheiruridæ and Encrinuridæ, while the broad anterior margin of the head suggests some of the Conocoryphidæ; he concludes that these resemblances have little value, as the other parts of the shield differ so largely from the representatives of these genera. In this I agree with him. The two genera are unlike all other trilobites and form a family type by themselves.

The genus is named after Mr. Lancaster D. Burling, of the United States National Museum, who found the only three nearly entire specimens of this interesting trilobite.

BURLINGIA HECTORI, new species

PLATE I, FIGURE 8

Dorsal shield small; longitudinally broad oval; slightly convex. Cephalon one-fourth the length of the complete dorsal shield, semicircular in outline, with genal angles prolonged into short slender spines that scarcely extend beyond the extremity of the first or anterior thoracic segment; the posterior margin of the cephalon is nearly

[1] Moberg, 1903, Meddelande från Lunds Geol. Mineral. Inst. No. 5 (Geol. Fören. i Stockholm Förhandlingar, Bd. XXV, Häft 2, 1903, No. 219), pp. 93–102, pl. IV.

transverse except at the axial lobe, where it arches slightly forward; the slope from the central portion of the cephalon to the margin is unbroken by any furrow and there is no clearly defined or raised rim. Cranidium with a broad campanulate frontal limb that extends from the anterior base of the eyes obliquely outward and forward and directly forward from the glabella to the outer margin of the cephalon; the posterior limbs, on their inner side, occupy the space between the posterior base of the eye and the posterior margin of the cephalon and extend outward to the lateral margin with a gradually increasing width; there is no fixed cheek between the palpebral lobe and the glabella; palpebral lobe about one-third the length of the cephalon and situated a little back of the center; it is slightly elevated along the outer margin and slopes toward the dorsal furrow next to the glabella. Glabella about three-fifths the length of the cephalon; it has subparallel sides up to the front of the eyes, where the sides curve inward and unite to form an obtusely rounded outline; in front the glabella merges into the frontal limb, so as to make it difficult to indicate a line of division between them; the glabella is gently convex and more or less clearly marked by a narrow median ridge, and, on each side of the ridge, two pits that indicate transverse furrows, very much as do the pits on the glabella of *Oryctocephalus*[1]; there is no trace of an occipital furrow or segment. Free cheeks subquadrangular in outline; on their inner margin they support the visual surface of the eye and from there slope gently to the outer margin. The facial sutures cut the lateral margin of the cephalon some distance in front of the genal angle and extend wth a little backward curvature to the posterior base of the eye; after curving over the eye lobe they extend obliquely forward at an angle of about 50° to the margin.

Thorax with fourteen segments; the first is nearly transverse, but each succeeding pleural lobe bends back a little more than the one preceding it, so that the pleural lobe of the posterior segment is bent back parallel to the side of the pygidium; the central axis of the thorax is gently convex, with a low median ridge that rises into a minute node on the two anterior segments; it gradually widens from the first to the seventh segment, and then narrows a little at each segment back to the pygidium; the pleural lobes are flattened between the axial lobe and the angle where the pleuræ bend more or less backward; each pleura has a broad, shallow, direct furrow that extends from the inner end out to the backward curving portion of the pleuræ; the edge of the furrow and of the segment is marked by

[1] Walcott, 1886, Bull. U. S. Geol. Survey, No. 30, p. 210.

a narrow thread-like ridge; the pleuræ terminate in falcate extremities, some of which, on the two anterior segments, appear to have a very short, fine spine at the posterior termination of each pleura.

Pygidium a narrow, elongate, moderately convex, central plate without defined segments or pleural lobes; it has a small node at the anterior third of its length. None of the specimens show the posterior margin; it may have been a single, broad spine or it may have terminated with a slightly arched posterior margin.

The outer surface of the dorsal shield appears to have been minutely granular or smooth.

DIMENSIONS.—The most perfect specimen of the dorsal shield has a length of 7 mm.; greatest width, 5 mm. The other dimensions are as follows:

	mm.
Cephalon:	
Length	2.25
Width at posterior margin	4.74
Thorax:	
Length	1.75
Greatest width	5.00
Axial lobe, greatest width	1.50
Pleural lobe, greatest width	1.75
Pygidium:	
Length to line of contour of dorsal shield	1.50
Width at anterior end	.75

OBSERVATIONS.—This interesting trilobite has a cephalon much like that of *Schmalenseeia amphionura* Moberg,[1] but it differs in details, and the pygidium is quite unlike that of Dr. Moberg's species; the furrows and ridges on the pygidium of the latter are very similar to those of the thorax of *Burlingia*.

The stratigraphic horizon of this species is 2,400 feet above the Lower Cambrian or Olenellus fauna and 2,600 feet below the Upper Cambrian fauna. It is associated with *Zacanthoides spinosus, Ogygopsis klotzi, Oryctocephalus reynoldsi, Bathyuriscus rotundatus, Bathyuriscus ornatus,* and other species of the *Ogygopsis klotzi* fauna of Mount Stephen.

The specific name is given in recognition of Sir James Hector, the Canadian geologist and explorer who discovered the Hector or Kicking Horse Pass in 1858.

FORMATION AND LOCALITY.—Middle Cambrian: Ogygopsis shale of the Stephen formation, 2,400 feet (731.5 m.) above the Lower

[1] Moberg, 1903, Meddelande från Lunds Geol. Mineral. Inst. No. 5 (Geol. Fören. i Stockholm Förhandlingar, Bd. xxv, Häft 2, 1903, No. 219), pl. IV, figs. 1 and 2.

Cambrian and 2,600 feet (792.5 m.) below the Upper Cambrian: northwest slope of Mount Stephen, 3,000 feet (914.4 m.) above the Kicking Horse River, above Field, on the Canadian Pacific Railway, British Columbia, Canada.

Order OPISTHOPARIA Beecher

Family PARADOXIDÆ

ALBERTELLA, new genus

Dorsal shield elongate-ovate. Cephalon large, semicircular in outline, about one-fourth the length of the dorsal shield; genal angles extended into spines; cranidium subquadrangular in outline, with long palpebral lobes and narrow fixed cheeks; palpebral lobes elongate, with outer rims continued across the fixed cheeks as narrow ocular ridges; glabella subquadrilateral in outline, with short lateral furrows; strong occipital ring. The facial sutures cut the posterior border within the genal angles and pass inward and slightly forward to the base of the eyes, thence about the palpebral lobe, and forward with slight curvature to the front margin.

Thorax with seven segments; pleuræ terminating in short spines, those of the third or fourth segment in longer spines; pleural furrow with broad inner end largely filled in by an elongated tubercle.

Pygidium large, with central axis divided into several rings, and with the first, or first and second combined, anterior, anchylosed segments extended across the border into a long spine on each side.

GENOTYPE.—*Albertella helena,* new species.

STRATIGRAPHIC RANGE.—Upper beds of Lower Cambrian.

GEOGRAPHIC DISTRIBUTION.—Western Alberta, near the line of the Canadian Pacific Railway, Canada, and northern Montana, in the Lewis and Clark Forest Reserve.

OBSERVATIONS.—*Albertella* is a most interesting type of the order Opisthoparia and family Paradoxidæ. It should first be compared with the genus *Zacanthoides* Walcott,[1] which, in the British Columbia section, is first met with in strata 2,000 feet above the beds in which *Albertella* occurs. The cephalons of the two genera are generically the same. The thoracic segments are of the same type, but the third or fourth segment of the thorax of *Albertella* is extended into long pleural spines, and the thorax has seven instead of nine segments, as in *Zacanthoides.* The pygidium of *Albertella* has a long, strong spine extending from the pleural lobes of the first, or first and second combined, anterior segments, and a smooth border otherwise; the

[1] Walcott, 1888, American Jour. Sci., 3d ser., vol. XXXVI, p. 165.

pygidium of *Zacanthoides* has all the pleural segments extended as spines directly across the border.

The prominent differences between the two genera, then, are the extension in adult individuals of the third or fourth segment of the thorax in *Albertella,* and the presence on the pygidium of one pair of spines instead of many spines, as in *Zacanthoides.*

The extension of the third segment of the thorax occurs in the genera *Olenellus* Hall and *Mesonacis* Walcott,[1] and the spinose extension of the pleural elements of the pygidium occurs in *Parabolina* Salter,[2] *Hysterolenus* Moberg,[3] and other genera, but these other genera differ in so many other characters that it is unnecessary to make comparisons between them and *Albertella.*

ALBERTELLA HELENA, new species

PLATE 2, FIGURES 1–9

Dorsal shield of medium size; with the exception of spines, longitudinally elongate-ovate; moderately convex. Cephalon semicircular in outline, one-third the length of the dorsal shield; marginal border of medium width, slightly convex, delimited from the cheeks by a sharp, shallow furrow, and continued at the genal angles directly into long, slender spines that extend outward and backward to a line back of the union of the thorax and pygidium; posterior border narrow at the inner end next to the dorsal furrow, a little wider at the facial sutures, and arching a little forward before merging into the outer border at the genal spine; the posterior border is delimited from the cheeks by a narrow, shallow furrow that begins opposite the center of the occipital segment, and, arching forward a very little, passes into the furrow within the outer border. Cranidium convex, subquadrangular in outline exclusive of the extension of its postero-lateral limbs; the latter are of medium width, with nearly one-half of their area occupied by the posterior furrow and border. Fixed cheeks at the palpebral lobe one-third the width of the glabella; posteriorly they merge into the postero-lateral limbs; anteriorly they pass directly forward to the interborder furrow; palpebral lobe narrow, elongate, about three-fifths the length of the cephalon,

[1] Walcott, 1891, Tenth Ann. Rept. U. S. Geol. Survey, pls. LXXXII, LXXXIII, LXXXIV, LXXXV, and LXXXVII.

[2] Moberg and Möller, 1898, Meddelande från Lunds Geol. Fältklubb, No. 3 (Geol. Fören. i Stockholm Förhandlingar, Bd. XX, Häft 5, 1898, No. 187), pls. XII and XIII.

[3] Moberg, 1898, Meddelande från Lunds Geol. Fältklubb, No. 5 (Geol. Fören. i Stockholm Förhandlingar, Bd. XX, Häft 6, 1898, No. 188), pl. XVII, figs. 1–9.

bordered by a narrow, rounded rim that is continued obliquely inward and forward, as an ocular ridge, across the fixed cheek to the dorsal furrow opposite the anterior pair of glabellar furrows. Glabella, including occipital ring, subquadrilateral, with sides slightly curved inward and front broadly rounded, moderately convex; the average sized glabella is marked by a pair of short, shallow furrows that extend obliquely inward and backward about one-third the distance across the glabella, and a pair of nearly transverse, short furrows that divide it into a short lobe on each side and a large anterior frontal lobe; the latter has a short, shallow furrow on each side about midway of its length that extends directly inward toward the central third of the width of the glabella; the glabella of a crandidium 23 mm. in length has a pair of deep, oblique, posterior furrows, and, in advance of them, four pairs of faint, short, nearly transverse furrows, the posterior pair of which are between the strong, oblique, posterior furrows and the longitudinal, median third of the glabella; a small dorsal shield with a cephalon 1.3 mm. in length, shows the oblique, posterior glabellar furrow and two pairs of the anterior furrows; occipital furrow strong, sharply defined, and curving forward at its ends; occipital ring strong, rounded, arching slightly backward with its anterolateral angle extending forward. Free cheeks slightly convex, with the body rising from the inter-border furrow to the base of the elongate, low eye lobe. The facial sutures cut the posterior margin within the middle third of the distance from the dorsal furrow to the outer margin; they curve gently outward and then inward across the border, and thence with a slight sigmoid curve to the base of the eye lobe; arching over the latter, they extend forward with a slight outward arching to and across the frontal border, so as to cut the frontal margin within a longitudinal line drawn forward from the outer margin of the palpebral lobe.

Thorax with seven nearly transverse segments; axial lobe convex and arching slightly backward; a small, low node occurs at the center near the posterior margin, and a transverse, rounded, low ridge at each end next to the dorsal furrow; the pleura is nearly straight, somewhat flattened, and terminated by a sharp spine that extends obliquely outward and backward a short distance, except on the third segment, which has a strong spine extending backward nearly to a line opposite the posterior third of the pygidium; pleural furrow broad at the dorsal furrow and narrowing to its end at the base of the terminal spine; a rounded, elongate, subtriangular tubercle occupies its inner half; the anterior border of the pleura next to the dorsal furrow is a narrow, rounded ridge, which

widens gradually and passes directly into the terminal spine; the posterior border is a narrow, rounded ridge that merges into the base of the terminal spine.

Pygidium moderately convex, about one-fourth of the length of the dorsal shield, elongate, semicircular in outline; axial lobe convex, divided by five shallow, narrow, transverse furrows into five rings and a terminal section that is within the border; pleural lobes marked by the pleural furrows of four anchylosed segments that merge into the smooth border; a slender but strong, long spine extends from a strong base on each side of the pygidium; this spine appears to be the extension of the anterior anchylosed segment.

Surface finely granulose, with scattered larger granules on small specimens.

DIMENSIONS.—A dorsal shield 40 mm. in length has the following dimensions:

	mm.
Cephalon:	
Length	13.5
Width at posterior margin	31.5
Thorax:	
Length	17.0
Width at first segment	22.0
Pygidium:	
Length	9.5
Width	15.0

OBSERVATIONS.—A dorsal shield 2.7 mm. in length, with a cephalon 2.3 mm. long, has a fixed cheek nearly as wide as the glabella, an eye lobe fully one-half the length of the cephalon, and the glabella slightly expanded toward the front. A large cranidium, 23 mm. in length, has a glabella proportionally wider in front, and very strong, posterior, oblique furrows.

This species was first found in 1904, on Gordon Creek, Ovando Quadrangle, Montana, in argillaceous shales, a short distance above the supposed Flathead sandstones, in association with

Acrothele colleni, new species,
Wimanella simplex, new genus and new species,
Olenopsis,
Ptychoparia, and
Bathyuriscus, sp. a.

The stratigraphic position of this subfauna was not determined in Montana, owing to the break in the continuity of the section on Gordon Mountain.

The specific name is given in recognition of the discovery by Mrs.

Walcott, in 1907, of this species and the accompanying subfauna on Mount Bosworth, in the Canadian Rockies. Its position was determined to be at the summit of the Lower Cambrian portion of the section, 2,450 feet below the *Ogygopsis klotzi* fauna of Mount Stephen.

The subfauna at the Mount Bosworth locality includes

Micromitra (Iphidella) capta, new species.
Obolus parvus, new species,
Acrothele colleni, new species,
Wimanella simplex, new genus and new species,
Albertella bosworthi, new species.
Albertella helena, new species, and
Bathyuriscus, sp. a.

FORMATION AND LOCALITY.—Lower Cambrian: (1) Drift block of siliceous shale on the south slope of Mount Bosworth, on the "Continental Divide," one mile east of Hector, on the Canadian Pacific Railway, British Columbia, Canada; and (2) Wolsey argillaceous shale, on Gordon Creek, 4 miles (2.5 km.) above its union with Danaher Creek, at the southeast foot of Gordon Mountain, Lewis and Clark Forest Reserve, Montana, U. S. A.

ALBERTELLA BOSWORTHI, new species

PLATE 1, FIGURES 4–7

This species differs from the associated *Albertella helena* in its cephalon, thorax, and pygidium. In the cephalon the eye and palpebral lobe are more elongate and nearer proportionally to the outer margin. In the thorax the pleuræ of the fourth segment are extended into long spines instead of those of the third, as in *A. helena;* the pleural lobes and the entire thorax are narrower in proportion to the length. In the pygidium there are six rings in the axis instead of three or four, and two anchylosed pleural segments pass into the large lateral spines instead of one. Both species have seven thoracic segments and a finely granulated surface and are associated in the same layers of shale at the Mount Bosworth locality.

FORMATION AND LOCALITY.—Lower Cambrian: Drift block of siliceous shale on south slope of Mount Bosworth, on the "Continental Divide;" one mile east of Hector, on the Canadian Pacific Railway, British Columbia, Canada.

Family OLENIDÆ Salter

ORYCTOCARA, new genus

Dorsal shield small, elliptical. Cephalon semicircular in outline, from one-third to one-fourth the length of the dorsal shield; genal angles and free cheeks unknown; cranidium subquadrangular in outline exclusive of the narrow postero-lateral limbs; glabella subquadrangular in outline, with three lobes and an occipital ring; the lobes are separated by very slightly defined, transverse furrows terminating in round pits within the lateral margin of the glabella. The facial sutures cut the posterior margin of the head within the genal angles and pass inward and slightly forward to the base of the eye and thence about the palpebral lobe and forward with a slightly outward curvature to the frontal rim. Fixed cheeks broad. Eyes long, with the margin of the palpebral lobe extending across the fixed cheeks as an ocular ridge.

Thorax with eleven segments; pleuræ with straight furrows and abrupt, truncated ends.

Pygidium large, with central axis divided into several rings by transverse furrows, all of which extend across the pleural lobes to the outer margin.

GENOTYPE.—*Oryctocara geikiei,* new species.

OBSERVATIONS.—The cranidium of the cephalon of this genus is much like that of *Oryctocephalus* Walcott,[1] but the thorax and pygidium are unlike. The pleuræ are of the *Olenus* Salter type in having a straight median furrow, while the pygidium is broad and of the *Bathyuriscus*[2] type. (See pl. 1, fig. 2, of this paper.)

The genus is referred to the order Opisthoparia Beecher and to the family Olenidæ Salter.

Only one species from the central portion of the Middle Cambrian is now known.

ORYCTOCARA GEIKIEI, new species

PLATE 1, FIGURES 9, 10

Dorsal shield small, longitudinally elliptical in outline, moderately convex. Cephalon semicircular in outline, a little less than one-third the length of the dorsal shield; free cheeks and genal angles unknown; a narrow, rounded rim extends across the front of the cranidium and it is probable that it continued along the free cheeks and terminated in a small genal spine. Cranidium subquadrangular

[1] Walcott, 1886, Bull. U. S. Geol. Survey, No. 30, p. 210.

[2] Meek, 1873, Sixth Ann. Rept. U. S. Geol. Survey Territories for 1872, p. 484.

in outline exclusive of the postero-lateral limbs; the latter are elongate, subtriangular in outline, and with a narrow, transverse furrow within a rounded rim of medium width. Fixed cheek about two-thirds the width of the glabella and merging posteriorly into the postero-lateral limb and anteriorly extending to the frontal rim; there is no defined frontal limb, owing to the glabella extending to the furrow within the frontal rim; palpebral lobe narrow, rounded, about one-half the length of the cranidium, and with its outer rim extending across the fixed cheek as a narrow ocular ridge nearly parallel to the frontal rim of the cranidium; the palpebral lobe terminates a short distance back of the frontal margin of the glabella. Glabella subquadrangular; slightly narrower at the broadly rounded front than at the occipital ring, moderately convex; divided by four faint, transverse furrows into three transverse lobes, an anterior, terminal lobe and an occipital ring; the faint, transverse furrows terminate on each side in round pits a short distance from and within the margin; occipital ring narrow and rounded. Free cheeks unknown. The facial sutures cut the posterior margin on each side a short distance from the genal angle and extend inward and slightly forward to the base of the eyes; curving over the eyes they extend forward with a slight outward direction, so as to cut the front margin on a line with the outer edge of the palpebral lobe.

Thorax with eleven nearly transverse segments; the axial lobe is convex and one-half the width of the pleural lobes; the segments of the axial lobe have a deep transverse furrow with the margins elevated; the doublure on the front margin of each segment curves downward, so as to pass beneath the downward slope of the posterior half of the next segment in advance of it; the extremity of each segment curves slightly forward, so that the furrow passes out upon the pleura a little in advance of its position at the center of the axial lobe and in front of the pleural furrow; the pleura is straight, nearly flat, and terminating in a blunt, straight margin without spine or backward curvature; the most careful examination fails to reveal spine or falcate extremity; the entire side of the thorax appears as though a sharp knife had cut off the ends of all the pleura from the cephalon to the pygidium; the pleural furrows of each segment originate on a low swelling between the axial and pleural lobes of each segment and extend directly outward to nearly the end of the segment, where they fade away, so as to leave the end of the segment flat; the pleural furrows are about one-third of the width of the segment and arch forward a very little between its two extremities.

Pygidium large, moderately convex; anterior margin slightly arched, so as to join with the posterior segment of the thorax; posterior outline semicircular; axial lobe convex and about two-thirds the length of the pygidium; it is divided into seven transverse rings and a terminal section by transverse furrows; the pleural lobes slope gently from the axial lobe to the lateral and posterior margins; their entire surface is marked by the anchylosed segments, which are similar in appearance to the thoracic segments, except that their backward curvature increases until the pleuræ of the posterior segments are nearly parallel to the axis of the pygidium; the furrows and narrow ridges from the terminal segment of the axis extend backward with a slight inward curvature; all furrows and ridges terminate just within the outer margin in the same manner as those of the thoracic pleura.

Surface with relatively large granules on all parts of the dorsal shield.

DIMENSIONS.—A dorsal shield 7.25 mm. in length has the following dimensions:

	mm.
Cephalon:	
Length	1.75
Length of glabella	1.50
Width	2.50
Width of glabella	1.00
Thorax:	
Length	3.75
Width	4.00
Width of axial lobe at sixth segment	8.00
Width of pleural lobe	1.60
Pygidium:	
Length	1.75
Width at anterior margin	3.50

OBSERVATIONS.—This is a very rare species, as only one nearly entire specimen is known; this has the pygidium displaced and the free cheeks are missing. The combination of characters found in several genera is shown (*a*) in the cranidium, in which the glabella is like that of *Oryctocephalus* Walcott; (*b*) in the thorax, which is not unlike that of *Olenus* Salter; and (*c*) in the pygidium, which suggests in relative size and form the pygidium of *Bathyuriscus howelli* Walcott.[1] Among the associated fossils are *Micromitra (Iphidella) pannula* (White), *Ptychoparia piochensis* Walcott, *Ptychoparia cordilleræ* (Rominger), *Oryctocephalus reynoldsi* Reed, *Zacanthoides idahoensis*, new species, and *Bathyuriscus howelli* Walcott.

[1] Walcott, 1886, Bull. U. S. Geol. Survey, No. 30, p. 216.

FORMATION AND LOCALITY.—Middle Cambrian: Spence shale of the Ute formation, 2,755 feet (839.7 m.) below the Upper Cambrian in the Liberty Canyon section; Spence Gulch, a ravine running up into Danish Flat from Mill Canyon, about 15 miles (9.37 km.) west of Montpelier and 5 miles (3.12 km.) west-southwest of Liberty, Bear Lake County, Idaho, U. S. A.

Genus ZACANTHOIDES Walcott

ZACANTHOIDES IDAHOENSIS, new species

PLATE 3, FIGURES 1–11

Dorsal shield large for a species of this genus, moderately convex, longitudinally elliptical in outline. Cephalon semicircular in outline, one-third the length of the adult dorsal shield; bordered by a rounded rim of medium width that is continued into strong, sharp genal spines that extend backward about one-half the length of the thorax; the posterior border is narrow next to the glabella, from where it widens out to the intergenal spine within the line of the facial suture; beyond the facial suture it curves forward and merges into the lateral border at the base of the genal spine; the posterior intermarginal furrow is sharply defined, and occupies most of the space between the border and the facial suture; on the sides and front of the cephalon the intermarginal furrow is narrow and distinct. Cranidium with a large glabella, short, small antero-lateral limbs, and elongate, slender postero-lateral limbs that have a short, sharp, slender, intergenal spine extending outward and backward from the outer posterior margin; fixed cheeks scarcely more than the inner sides of the large palpebral lobes and a small, subtriangular area in front of the latter; postero-lateral limbs formed of the marginal border and strong, intermarginal furrows; a narrow frontal limb extends across between the glabella and the interborder furrow; palpebral lobe about three-fifths the length of the cranidium and bordered by a narrow, rounded rim that begins, posteriorly, near the median axis opposite the occipital ring, and, curving outward, forward, and then inward, terminates at the dorsal furrow beside the glabella; it is separated from the body of the lobe by a rounded, shallow furrow. Glabella elongate, subquadrilateral in outline, moderately convex in front, sides nearly straight, broadly rounded, and separated from the fixed cheeks and palpebral lobes by a narrow, distinct furrow; surface marked by a pair of posterior furrows that extend obliquely inward, so as to outline two small subtriangular lobes, and two pairs of short, more transverse furrows; the anterior pair is nearly opposite the anterior end of the

palpebral lobe, and the second pair about half way between them and the outer ends of the posterior pair; on some specimens a fourth pair is faintly defined on the large anterior lobe close to the dorsal furrow opposite the rounded angle formed by the sides and rounded front of the glabella. Occipital ring strong, rounded, broadest at the center, and narrowing gradually toward the ends; marked by a small central node near the posterior margin and a rounded, small, depressed tubercle at about one-half the distance between the central node and the dorsal furrow; occipital furrow distinct, narrow, and nearly transverse. Free cheeks large, body gently convex, and rising from the interborder furrow to the base of the elongate, low eye lobe. The facial sutures cut the posterior margin just outside of the intergenal spine and, curving abruptly inward, extend to the posterior base of the eye lobe; arching over the latter, they extend forward and slightly outward with a gentle sigmoid curve, so as to cut the outer margin at a distance from the median line of the cranidium equal to the width of the glabella.

Thorax with nine segments; axial lobe convex, a little wider than the pleural lobes exclusive of the spinose terminations of the pleuræ; a small elongate node occurs at the center on the posterior half of each segment, except on the fifth, which has a long, slender, backward-extending spine; on each side, about half way between the center and the dorsal furrow and nearest the anterior margin, there is a rounded, low tubercle, and on the more perfectly preserved specimens a low, rounded, transverse ridge on each side next to the dorsal furrow; pleural lobes slightly convex; each pleura has a strong furrow that is broad at the inner end next to the dorsal furrow, from whence it narrows gradually to its sharp extremity near the posterior outer end of the pleura just within the base of the terminal spine; a rounded, elongate, subtriangular tubercle occupies much of the broad inner end of the furrow; the front border of each pleura is narrow next to the dorsal furrow; it gradually widens toward the outer end and terminates in a strong, long, backward-extending spine; the narrow posterior border merges into the base of the terminal spine; in most specimens the backward curvature of the anterior margin of the pleura is so abrupt that an obtuse angle is formed, while in some the margin curves gradually into the terminal spine.

Pygidium of medium size; axial lobe convex, narrow, broader than the pleural lobes, divided by narrow, transverse furrows into four rings and a terminal section that, in large specimens, has a slight, transverse furrow that delimits a fifth narrow ring; on the

pleural lobes four anchylosed segments are outlined by narrow, deep furrows; only the two anterior preserve any trace of the pleural furrow, and these are very short and obscure; the pleural segments are mainly made up of the thickened, broad, anterior border and the strong, backward-extending, rounded spines; the outer border is usually obscured until after the fourth spine is passed, and even then in some specimens the short fifth and sixth pairs of spines obscure it; on other specimens the posterior spines are so slightly developed that the outline of the border is preserved.

Surface finely granular.

DIMENSIONS.—A dorsal shield 38 mm. in length has the following dimensions:

	mm.
Cephalon:	
Length	13.0
Width at base	30.0
Length of eye lobe	7.0
Length of glabella	10.0
Width of glabella, base	6.0
Width of glabella, front	6.5
Thorax:	
Length	17.5
Width	21.0
Axial lobe, anterior segment	8.0
Axial lobe, posterior segment	4.5
Pleural lobe, anterior segment	6.5
Pleural lobe, posterior segment	3.0
Pygidium:	
Length	7.5
Width	10.0
Axial lobe, anterior segment	4.5
Axial lobe, posterior segment	2.5

The preceding description is based on adult specimens averaging 38 to 45 mm. in length. A large number of young and small specimens were found in association with the larger adults, some of which exhibit stages of growth. A specimen 1.9 mm. in length (fig. 5) preserves the cranidium and five segments of the thorax. The glabella widens out toward the front, and the occipital furrow is very faint; the base of the palpebral lobe is farther out on the posterior margin than in the adult, and its anterior end is at the dorsal furrow and nearer the antero-lateral, rounded angle of the glabella. The pleural lobe has somewhat broader, more direct furrows on the pleura, and the spine of the fifth segment is very large; another important character is the greater extension of the terminal spines of the third thoracic segment—a character unknown in the

later stages of growth of this species and a character persistent in *Albertella helena,* which occurs over 2,000 feet (609.6 m.) lower than the horizon of *Zacanthoides spinosus* (Rominger) in the Cambrian section of the Canadian Rocky Mountains. It also occurs in the adult forms of *Mesonacis vermontana*[1] and other trilobites of the *Olenellus* fauna. A specimen of the entire dorsal shield 3.2 mm. in length has the same widening of the glabella toward the front as the smaller specimen, but the base of the palpebral lobes have drawn in toward the glabella, and the glabella has extended forward beyond the anterior extremities of the palpebral lobes; the thorax has only adult characters, except that the third segment appears to have on one side a stronger terminal spine, and there are but seven segments; the spines on the border of the pygidium are short, and but four can be seen on each side. Specimens 8 mm. in length have all adult characters in the cephalon and thorax, with the exception of the terminal spines of the pygidium, which are shorter and less clearly defined at the crossing of the border.

OBSERVATIONS.—This species occurs abundantly in Idaho. When collecting it I thought it to be *Zacanthoides typicalis,*[2] but on direct comparison with that species it was found to differ in having the posterior end of the palpebral lobe nearer the glabella; the glabella proportionally narrower in front, and larger antero-lateral parts of the fixed cheek; a broader thoracic axis in proportion to the pleural lobes; a long median spine on the fifth instead of seventh segment; a larger pygidium, with broader pleural lobes, more rings on the axis, and more terminal spines on the pygidium. It is found to differ from *Zacanthoides spinosus* (Walcott)[3] in having the glabella less expanded toward the front; palpebral lobes nearer the glabella at their posterior end; smaller antero-lateral parts of the fixed cheek; absence of a strong occipital spine; in the thorax it differs in having a long median spine on the central axis at the fifth segment instead of the seventh, and the axial lobe is proportionally wider; the pygidium differs in having four rings on the axis instead of three; the axial lobe is proportionally longer, and the spines on the pygidium differ in details of shape and number. The three species occur at the same relative geological horizon, but are widely separated. *Z. typicalis* occurs at Pioche, Nevada, 350 miles south-southwest of the locality of *Z. idahoensis* at Spence Gulch, 15 miles

[1] Walcott, 1891, Tenth Ann. Rept. U. S. Geol. Survey, pl. LXXXVII, fig. 1*a;* see also pls. LXXXIV and LXXXV.

[2] Walcott, 1886, Bull. U. S. Geol. Survey, No. 30, p. 183.

[3] Walcott, Mon. U. S. Geol. Survey, vol. VIII, 1884, p. 63; and Bull. U. S. Geol. Survey, No. 30, 1886, p. 184.

west of Montpelier, Idaho; *Z. spinosus* is from Mount Stephen, in British Columbia, 685 miles north-northwest of Spence Gulch. Among the associated fossils are *Bathyuriscus howelli* Walcott, *Oryctocephalus reynoldsi* Reed, *Oryctocara geikiei* Walcott, *Micromitra (Iphidella) pannula* (White).

FORMATION AND LOCALITY.—Middle Cambrian: Spence shale of the Ute formation, 2,755 feet (839.7 m.) below the Upper Cambrian in the Liberty Canyon section; Spence Gulch, a ravine running up into Danish Flat from Mill Canyon, about 15 miles (9.37 km.) west of Montpelier, and 5 miles (3.12 km.) west-southwest of Liberty, Bear Lake County, Idaho, U. S. A.

Genus NEOLENUS Matthew

NEOLENUS INFLATUS, new species

PLATE 5, FIGURES 1–5

Dorsal shield large, elongate-elliptical in outline; axial lobe strongly convex. Cephalon semicircular in outline, with the genal angles produced into sharp spines about one-half the length of the cephalon; a narrow, rounded rim extends across the front of the cranidium, and, widening a little, runs along the outer margins of the free cheeks to the genal angles. The facial sutures cut the posterior margin well within the genal angles with an outward direction to the posterior furrow, where they curve inward and forward to the base of the eye lobe; arching over the eye lobes they curve outward to about the line of the outer rim of the palpebral lobe, forward to the frontal rim, and then obliquely inward across the rim to the front margin. Cranidium with a prominent, tumid glabella, narrow fixed cheeks, small antero-lateral limbs, and strong postero-lateral limbs. Glabella large, convex; the frontal lobe is inflated and, in all but young, small specimens, overhangs the frontal rim; the sides gradually expand from the occipital ring to the broadly rounded front, which extends forward to, and lies parallel with, the furrow within the rounded frontal rim; the anterior half of the glabella is taken up by the expanded, anterior lobe and the posterior half is divided into four narrow lobes by shallow furrows that extend obliquely inward and slightly backward nearly to the median line; in some specimens, especially the young, the furrows are very faintly defined; occipital ring separated from the glabella by a narrow, shallow furrow; it is broad, moderately convex, and with a strong, long, sharp, arching spine that extends back over the thorax nearly to the pygidium; the base of the spine occupies nearly the entire width of the occipital ring at its center. Fixed cheeks

about one-fourth the width of the glabella, gently convex and merging into the anterior and posterior limbs; the posterior limb is about twice as long as deep below the eye lobe and marked by a strong furrow within the broad, slightly convex posterior border; palpebral lobe small, 7 mm. long in a cephalon having a length of 35 mm. at the eye lobes; it is bordered by a rounded rim that continues obliquely forward across the fixed cheek and merges into the side of the glabella. Free cheeks large, gently convex; bordered by a rounded rim that is continued posteriorly into a spine; posterior margin rather broad and about one-third the length of the margin between the genal angles and the occipital ring; eye lobe small and not high. The genal spine is situated some distance out from the central axis, so that it clears the terminal spines of the thoracic pleuræ.

Thorax with seven nearly transverse segments; axial lobe convex, with the segments slightly rounded and a small node at the center of each; a low, narrow, transverse ridge occurs on each side near the union of the axial and pleural lobes; pleural lobes a little wider than the axial lobe and slightly convex; the pleura is straight, out to the backward curving, terminal spine; the narrow pleural furrow originates at the inner end next to the axis and passes obliquely outward, terminating just back of the center of the pleura at the base of the terminal spine; the latter has a strong base and narrows rapidly to a sharp point as it extends outward and backward a short distance.

Pygidium large, moderately convex; anterior margin nearly transverse, posterior outline broadly semi-elliptical; axial lobe convex and narrowing gradually from the anterior margin to the terminal ring at the narrow posterior border; it is divided into ten strong, rounded, transverse rings and a terminal section by ten narrow furrows; the terminal section in large specimens has a transverse pit on each side of its center that indicates an eleventh ring; a low node is indicated at the center of each ring, and a low, narrow, transverse swelling occurs near the dorsal furrow on each side; in a pygidium 8 mm. in length there are nine clearly defined, axial rings, a faint, tenth ring, and an elongate, rounded, terminal section; pleural lobes slightly convex out to the spinose border, which is flattened between the termination of the pleural grooves and its outer edge; the eight marginal spines on each side are similar to those of the pleural lobes of the thorax with the exception of the posterior ones, which extend directly backward; the space between the axial lobe and the margin is marked by the pleural furrows and the narrow

furrows indicating seven anchylosed segments; the posterior furrows are nearly parallel to the sides of the axial lobe; the furrows all terminate on the inner portion of the outer border, the pleural furrows with a slight, elongate pit just within the border.

Surface with variously arranged, irregular, raised lines or narrow, sharp ridges; on the glabella they are very slender and arranged in a somewhat concentric manner, although they are broken and irregular; on the fixed and free cheeks the raised lines are much stronger, irregular, and more or less anastomosing; on the thoracic segments the short, irregular raised lines cross the segments of the axis on each side between the central node and the dorsal furrow, and on the pleuræ they extend obliquely across the raised spaces between the furrows; the pygidium has about the same markings at the thorax except on the flattened border, where the short, elevated, irregular lines extend across the border.

DIMENSIONS.—There are two small, nearly entire dorsal shields. One, having a length of 24 mm. exclusive of the posterior spines of the pygidium, has the following dimensions:

	mm.
Cephalon:	
Length	9.5
Width at posterior margin	11.5
Thorax:	
Length	8.0
Width at first segment	14.0
Pygidium:	
Length	7.5
Width at anterior margin	10.0

A large cranidium, 52 mm. in length, has the following dimensions:

	mm.
Glabella:	
Length	42.0
Width at posterior margin	88.0
Width at occipital furrow	26.0
Width just in front of ocular ridge	34.0
Palpebral rim, length	7.0

A large pygidium, 58 mm. in length, has the following dimensions:

	mm.
Width at anterior margin	76.0
Axial lobe, length	52.0
Axial lobe, width at anterior margin	19.0
Axial lobe, width at anterior segment	19.0
Axial lobe, width at posterior section	10.0
Pleural lobe, width at anterior margin	28.5

Hypostoma strongly convex, elongate, strongly rounded at the base, narrowing toward the broadly rounded posterior margin; border slightly flattened, with a rounded edge; this edge is arched slightly upward on the sides at about the posterior third of the length of the hypostoma; a shallow furrow crosses the posterior end of the convex body a short distance in front of the posterior margin and subparallel to it; the alate lateral limbs are subtriangular in outline and slightly convex. The surface is marked by fine, irregular, elevated lines that are subparallel to the rim on the margin and roughly concentric on the body. An hypostoma 26 mm. in length has a width of 28 mm. at its base, 15 mm. at the arches in the margin or at the posterior third; convexity at center, 5 mm.

The above-described hypostoma is associated with this species, *Neolenus superbus,* and a less convex hypostoma which is referred to the latter species.

OBSERVATIONS.—This large species and the associated *Neolenus superbus* appear to mark the extreme development in size of species of *Neolenus* and its latest occurrence in Cambrian time. Fragments of both species are abundant at one locality, and a few entire specimens have been found. It is the largest of the Cordilleran Cambrian trilobites, some of the partially entire specimens indicating a length of 160 mm., width 83 mm.

The most nearly related species is *Neolenus superbus,* from which *Neolenus inflatus* differs in having an inflated glabella, a longer pygidium, and in minor details of the pleuræ of the thoracic segments, pygidium, and cephalon. The inflated glabella, long pygidium with ten rings and spinose terminations of the thoracic pleuræ, separate it from *Neolenus serratus* (Rominger),[1] the type of the genus. The latter also has a granular surface and falcate terminations to the pleuræ of the thoracic segments, and the faunal horizon of *N. serratus* is 1,900 to 2,125 feet below that of *N. inflatus.*

FORMATION AND LOCALITY.—Middle Cambrian: 1,895–2,140 feet (605–653.8 m.) below the Upper Cambrian and about 2,000 feet (609.6 m.) above the beds containing *Zacanthoides typicalis* Walcott and *Bathyuriscus howelli* Walcott, the horizon which is correlated with the horizon carrying *Neolenus serratus* (Rominger) in British Columbia,[2] in thin-bedded limestones of the Marjum formation, in ridge on east side of Wheeler Amphitheater, east of Antelope Springs, House Range, Millard County, Utah, U. S. A.

[1] *Ogygia serrata* Rominger, 1887, Proc. Acad. Nat. Sci. Philadelphia, p. 13.

[2] This British Columbia horizon is given in detail in the Formation and locality of *Burlingia hectori.*

NEOLENUS INTERMEDIUS, new species

PLATE 6, FIGURES 1–7

This species, as its name implies, is an intermediate form between *N. superbus* and *N. inflatus*. It differs from both of those species in the absence of an occipital spine; and in having the sides of the glabella more nearly parallel and with the glabella less expanded in front, and somewhat more pointed or less abruptly rounded. The pleural lobes of the thorax have a terminal spine on the pleuræ extending backward somewhat more abruptly than in either of the other species.

The pygidium has five or six rings in the axial lobe and a terminal segment. *N. inflatus* has ten or eleven rings in the axial lobe and *N. superbus* has eight rings; *N. intermedius* has the same number of terminal spines as *N. superbus,* but the spines are curved backward much more than in the latter species.

As far as known, this species does not attain the size of either *N. superbus* or *N. inflatus*. The largest cephalon in the collection has a length of 35 mm. The proportions of the head and pygidium are about the same as *N. superbus*. The hypostoma referred to this species is proportionally broader and with a larger body proportionally than that of *N. inflatus* or *N. superbus*. In other respects it is very much like the hypostoma of *N. superbus*.

DIMENSIONS.—A dorsal shield 74 mm. in length has the following dimensions:

	mm.
Cephalon:	
Length	26.5
Length of glabella	21.0
Length of eye lobe	4.4
Width at posterior margin	44.0
Width of glabella at posterior margin	13.5
Width of glabella at anterior end	15.0
Thorax:	
Length	27.0
Width	41.0
Width of axial lobe at first segment	13.0
Width of pleural lobe at first segment	13.5
Pygidium:	
Length	20.5
Width	35.0
Width of axial lobe at anterior ring	10.0
Width of axial lobe at posterior ring	7.5

The surface markings of this species are much like those of *N. superbus* and *N. inflatus,* but very much finer. On a cranidium 11 mm. in length the surface appears smooth, except under a strong lens.

FORMATION AND LOCALITY.—Middle Cambrian: 1,895–2,140 feet (605–653.8 m.) below the Upper Cambrian and about 2,000 feet (609.6 m.) above the beds containing *Zacanthoides typicalis* Walcott and *Bathyuriscus howelli* Walcott, the horizon which is correlated with the horizon carrying *Neolenus serratus* (Rominger) in British Columbia,[1] in thin-bedded limestones of the Marjum formation, in ridge on east side of Wheeler Amphitheater, east of Antelope Springs, House Range, Millard County, Utah, U. S. A.

NEOLENUS INTERMEDIUS PUGIO, new variety

PLATE 6, FIGURES 8, 9

This variety is founded on four specimens of a pygidium that has four rings and a terminal segment in the axial lobe, four marginal spines on each side and three clearly defined anchylosed pleural segments marked by oblique pleural furrows. A specimen 11 mm. in length has a width at the front of 36 mm. The axial lobe has a width of 5 mm. at the first segment and 3 mm. at the terminal segment.

This variety differs from *N. intermedius* in having four instead of five marginal spines on each side of the pygidium, four axial rings instead of five and a shorter terminal section to the axial lobe. A fragment of the outer surface shows it to have been of the same type as that of *N. superbus.*

FORMATION AND LOCALITY.—Middle Cambrian: 1,895–2,140 feet (605–653.8 m.) below the Upper Cambrian and about 2,000 feet (609.6 m.) above the beds containing *Zacanthoides typicalis* Walcott and *Bathyuriscus howelli* Walcott, the horizon which is correlated with the horizon carrying *Neolenus serratus* (Rominger) in British Columbia,[1] in thin-bedded limestones of the Marjum formation, in ridge on east side of Wheeler Amphitheater, east of Antelope Springs, House Range, Millard County, Utah, U. S. A.

[1] This British Columbia horizon is given in detail in the Formation and locality of *Burlingia hectori.*

FORMATION AND LOCALITY.—Middle Cambrian: Spence shale of the Ute formation, 2,755 feet (839.7 m.) below the Upper Cambrian in the Liberty Canyon section; Spence Gulch, a ravine running up into Danish Flat from Mill Canyon, about 15 miles (9.37 km.) west of Montpelier and 5 miles (3.12 km.) west-southwest of Liberty, Bear Lake County, Idaho, U. S. A.

Genus ZACANTHOIDES Walcott

ZACANTHOIDES IDAHOENSIS, new species

PLATE 3, FIGURES 1–11

Dorsal shield large for a species of this genus, moderately convex, longitudinally elliptical in outline. Cephalon semicircular in outline, one-third the length of the adult dorsal shield; bordered by a rounded rim of medium width that is continued into strong, sharp genal spines that extend backward about one-half the length of the thorax; the posterior border is narrow next to the glabella, from where it widens out to the intergenal spine within the line of the facial suture; beyond the facial suture it curves forward and merges into the lateral border at the base of the genal spine; the posterior intermarginal furrow is sharply defined, and occupies most of the space between the border and the facial suture; on the sides and front of the cephalon the intermarginal furrow is narrow and distinct. Cranidium with a large glabella, short, small antero-lateral limbs, and elongate, slender postero-lateral limbs that have a short, sharp, slender, intergenal spine extending outward and backward from the outer posterior margin; fixed cheeks scarcely more than the inner sides of the large palpebral lobes and a small, subtriangular area in front of the latter; postero-lateral limbs formed of the marginal border and strong, intermarginal furrows; a narrow frontal limb extends across between the glabella and the interborder furrow; palpebral lobe about three-fifths the length of the cranidium and bordered by a narrow, rounded rim that begins, posteriorly, near the median axis opposite the occipital ring, and, curving outward, forward, and then inward, terminates at the dorsal furrow beside the glabella; it is separated from the body of the lobe by a rounded, shallow furrow. Glabella elongate, subquadrilateral in outline, moderately convex in front, sides nearly straight, broadly rounded, and separated from the fixed cheeks and palpebral lobes by a narrow, distinct furrow; surface marked by a pair of posterior furrows that extend obliquely inward, so as to outline two small subtriangular lobes, and two pairs of short, more transverse furrows; the anterior pair is nearly opposite the anterior end of the

palpebral lobe, and the second pair about half way between them and the outer ends of the posterior pair; on some specimens a fourth pair is faintly defined on the large anterior lobe close to the dorsal furrow opposite the rounded angle formed by the sides and rounded front of the glabella. Occipital ring strong, rounded, broadest at the center, and narrowing gradually toward the ends; marked by a small central node near the posterior margin and a rounded, small, depressed tubercle at about one-half the distance between the central node and the dorsal furrow; occipital furrow distinct, narrow, and nearly transverse. Free cheeks large, body gently convex, and rising from the interborder furrow to the base of the elongate, low eye lobe. The facial sutures cut the posterior margin just outside of the intergenal spine and, curving abruptly inward, extend to the posterior base of the eye lobe; arching over the latter, they extend forward and slightly outward with a gentle sigmoid curve, so as to cut the outer margin at a distance from the median line of the cranidium equal to the width of the glabella.

Thorax with nine segments; axial lobe convex, a little wider than the pleural lobes exclusive of the spinose terminations of the pleuræ; a small elongate node occurs at the center on the posterior half of each segment, except on the fifth, which has a long, slender, backward-extending spine; on each side, about half way between the center and the dorsal furrow and nearest the anterior margin, there is a rounded, low tubercle, and on the more perfectly preserved specimens a low, rounded, transverse ridge on each side next to the dorsal furrow; pleural lobes slightly convex; each pleura has a strong furrow that is broad at the inner end next to the dorsal furrow, from whence it narrows gradually to its sharp extremity near the posterior outer end of the pleura just within the base of the terminal spine; a rounded, elongate, subtriangular tubercle occupies much of the broad inner end of the furrow; the front border of each pleura is narrow next to the dorsal furrow; it gradually widens toward the outer end and terminates in a strong, long, backward-extending spine; the narrow posterior border merges into the base of the terminal spine; in most specimens the backward curvature of the anterior margin of the pleura is so abrupt that an obtuse angle is formed, while in some the margin curves gradually into the terminal spine.

Pygidium of medium size; axial lobe convex, narrow, broader than the pleural lobes, divided by narrow, transverse furrows into four rings and a terminal section that, in large specimens, has a slight, transverse furrow that delimits a fifth narrow ring; on the

	mm.
Thorax:	
Length	24.00
Width	30.00
Width of axial lobe at first segment	10.00
Width of pleural lobe at first segment	10.00
Pygidium:	
Length	18.00
Width	26.00
Width of axial lobe at anterior ring	9.00
Width of axial lobe at posterior ring	6.50
Hypostoma:	
Length	29.00
Length of body	26.00
Width	18.00
Width at base	23.00
Width at junction with head	33.00
Greatest width of body	19.00

OBSERVATIONS.—This species attains a large size. A cephalon and six thoracic segments has a length of 73 mm., a width of thorax of 70 mm.; with the seventh segment and the pygidium, exclusive of spines, the entire shield would have had a length of 107 mm. Fragments occur that indicate even a larger size.

Neolenus superbus and the associated *Neolenus inflatus* have many characters common to each; both attain a large size, both have small eyes, subquadrilateral glabellas, spinose genal angles, seven thoracic segments, spinose terminations to pleural segments and border of pygidium, occipital and thoracic median spines, lined surfaces, and resemble each other in minor details. The two species differ in the glabella of *N. superbus* being slightly convex with nearly parallel sides, instead of being inflated and expanded toward the front. The pygidium of *N. superbus* has seven axial rings and five spines on the border; that of *N. inflatus* has nine rings and eight spines. *Neolenus serratus* (Rominger)[1] has a broader dorsal shield, falcate terminations to the pleural segments, four rings on the axis of the pygidium, a subquadrangular glabella and genal spines that are formed by the union of the outer border and posterior border, instead of being a continuation of the outer border, as in *N. superbus* and *N. inflatus*. The surface of *N. serratus* is granular and not raised lines, as in *N. superbus*.

FORMATION AND LOCALITY.—Middle Cambrian: 1,895–2,140 feet (605–653.8 m.) below the Upper Cambrian and about 2,000 feet (609.6 m.) above the beds containing *Zacanthoides typicalis* Walcott and *Bathyuriscus howelli* Walcott, the horizon which is correlated

[1] *Ogygia serrata* Rominger, 1887, Proc. Acad. Nat. Sci. Philadelphia, p. 13.

with the horizon carrying *Neolenus serratus* (Rominger) in British Columbia,[1] in thin-bedded limestones of the Marjum formation, in ridge on east side of Wheeler Amphitheater, east of Antelope Springs, House Range, Millard County, Utah, U. S. A.

Genus BATHYURISCUS Meek

BATHYURISCUS ORNATUS, new species

PLATE 1, FIGURES 1–3

Dorsal shield small for the genus, longitudinally oval in outline, moderately convex. Cephalon semicircular in outline; a little less than one-third the length of the dorsal shield; bordered by a narrow, rounded margin that passes, at the rounded genal angle, into the very narrow posterior border; the interborder furrow is sharply defined all about the outer border, and within the posterior border it is a straight, rather broad, shallow furrow. Cranidium large, with very small antero-lateral and large postero-lateral limbs; the former are nearly as long as broad and separated from the fixed cheeks by the strong ocular ridges; the postero-lateral limbs and fixed cheeks merge into each other so as to form subtriangular areas, with the narrow palpebral lobes on their front outer margins for about one-third of their length; the palpebral lobes are small, about one-fourth to one-fifth the length of the cranidium and bordered by a strong, narrow, rounded rim that extends across the fixed cheeks to the dorsal furrow, beside the glabella.

Glabella large, a little wider in front than at the occipital furrow and with slightly diverging sides; front broadly rounded; surface marked by four pairs of furrows, the posterior of which extends obliquely inward across the posterior portion nearly to the center, so as to separate a small subtriangular lobe on each side; the three anterior pairs of furrows are short, close to the dorsal furrow, and about equal distances from each other. Occipital ring very narrow at its ends, from where it broadens rapidly to its full width; a short, oblique furrow occurs on each side that is subparallel to the posterior pair of glabellar furrows, that serve to separate the central portion of the occipital ring from its end sections; occipital furrow narrow, distinct, transverse, and terminating in advance of the posterior intermarginal furrows of the fixed cheeks. Free cheeks small, elongate, and with rounded posterior angles; eye lobes small. The facial sutures cut the posterior margin just within the genal angle and extend obliquely forward and inward with a slight sigmoid

[1] This British Columbia horizon is given in detail in the Formation and locality of *Burlingia hectori*.

curvature to the base of the eye lobes; curving over and around the eye lobes, they pass forward and a little outward to the front margin; the distance between the eye lobes and margin is about the length of the eye lobe.

Thorax with eight segments; axial lobe moderately convex, about as wide as the pleural lobes in partially compressed specimens; on the outer side of each segment a rounded, transverse node or ridge is separated from the main body of the segment by a slightly oblique furrow transverse to the segment; the furrows are similar to those crossing the occipital ring; pleural lobes slightly convex and with the extremities of the pleuræ bending slightly downward; each pleura has very narrow, raised margins next to the axial lobe that gradually broaden and slope inward out to the slight geniculation, where they form an elongated node with straight outer edge, which, touching against the nodes upon the adjoining pleura, forms an elongated, rounded node transversely divided by the line separating the pleuræ; an elongated, tapering, rounded node, with its base at the dorsal furrow, occupies the inner half of the pleura; a narrow groove on each side of the node united to form a shallow pleural furrow that terminates within the somewhat abruptly pointed outer extremity of each pleura.

Pygidium of medium size, about one-fourth the length of the dorsal shield; anterior margin nearly transverse, except where it bends backward near the outer ends; posterior outline semicircular; axial lobe moderately convex and tapering gradually toward the posterior section; it is divided by four transverse furrows into four rings and a terminal segment; four anchylosed pleural segments are outlined on the pleural lobes on each side of the axial lobe by furrows that progressively curve backward from the first to the posterior adjoining the terminal segment; the furrows all terminate within the narrow, slightly flattened border.

Surface finely granulose.

DIMENSIONS.—A dorsal shield 13.5 mm. in length has the following dimensions:

	mm.
Cephalon:	
Length	5.0
Length of eye lobe	0.9
Width at posterior margin	9.0
Width of glabella at posterior margin	2.4
Thorax:	
Length	5.5
Width	8.5
Width of axial lobe at first segment	2.3
Width of axial lobe at eightb segment	1.9

Pygidium:	mm.
Length	2.9
Width at union with thorax	6.0

OBSERVATIONS.—This species is rather rare at Mount Stephen, although 18 specimens were found in the collections of 1907. The largest specimen of the dorsal shield has a length of 18 mm. The strong triangular nodes on the pleural portion of the segments next to the axial lobe and the nodes at the geniculation, combined with the clearly defined furrows about them, give the thorax a very striking ornamental effect that leads to giving the specific name *ornatus*. This type of thoracic segment serves to distinguish the species from all other species of the genus *Bathyuriscus*. The associated *B. rotundatus* (Rominger)[1] has quite a different pleural segment, larger pygidium in proportion to the length of the dorsal shield, and nine thoracic segments instead of the eight, as in *B. ornatus*.

Another associated species, *Bathyuriscus occidentalis* (Matthew),[2] has nine segments with an open pleural furrow, relatively smaller pygidium, and larger free cheek.

FORMATION AND LOCALITY.—Middle Cambrian: Ogygopsis shale of the Stephen formation, 2,400 feet (731.5 m.) above the Lower Cambrian and 2,600 feet (792.5 m.) below the Upper Cambrian; northwest slope of Mount Stephen, 3,000 feet (914.4 m.) above the Kicking Horse River, above Field, on the Canadian Pacific Railway, British Columbia, Canada.

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[1] *Embolimus rotundatus* Rominger, 1887, Proc. Acad. Nat. Sci. Philadelphia, p. 16.

[2] *Dolichometopus occidentalis* Matthew, 1899, Trans. Roy. Soc. Canada for 1899, 2d ser., vol. v, sec. 4, No. 2, p. 49.

DESCRIPTION OF PLATE 1

Page

Bathyuriscus ornatus, new species..... 39

FIG. 1. A broken specimen, showing character of cephalon and thorax. U. S. National Museum, Catalogue No. 53420.

2. A small nearly entire dorsal shield, with the exception of the free cheeks. U. S. National Museum, Catalogue No. 53421.

3. Two segments of the thorax enlarged to show the details of the axial and pleural lobes. U. S. National Museum, Catalogue No. 53423.

The specimens represented by figures 1–3 are from the Middle Cambrian Ogygopsis shale of the Stephen formation, 2,400 feet (731.5 m.) above the Lower Cambrian, on the northwest slope of Mt. Stephen, near Field, British Columbia.

Albertella bosworthi, new genus and new species..... 22

FIG. 4. Cephalon, showing character of the palpebral lobes. Compare this with the cephalon of *Albertella helena* on pl. 2, figs. 1, 4, and 5. U. S. National Museum, Catalogue No. 53413.

5. A specimen showing the character of the thorax and pygidium. U. S. National Museum, Catalogue No. 53416.

6. Pygidium, which compare with pygidium of *A. helena* pl. 2, fig. 2. U. S. National Museum, Catalogue No. 53415.

7. Inner side of a very small pygidium. U. S. National Museum, Catalogue No. 53406.

The specimens represented by figures 4–7 are from a drift block of Lower Cambrian shales found on the slopes of Mt. Bosworth, just north of the Canadian Pacific Railway, one mile (0.62 km.) east of Hector, British Columbia.

Burlingia hectori, new genus and new species..... 15

FIG. 8. A nearly entire specimen greatly enlarged. U. S. National Museum, Catalogue No. 53418.

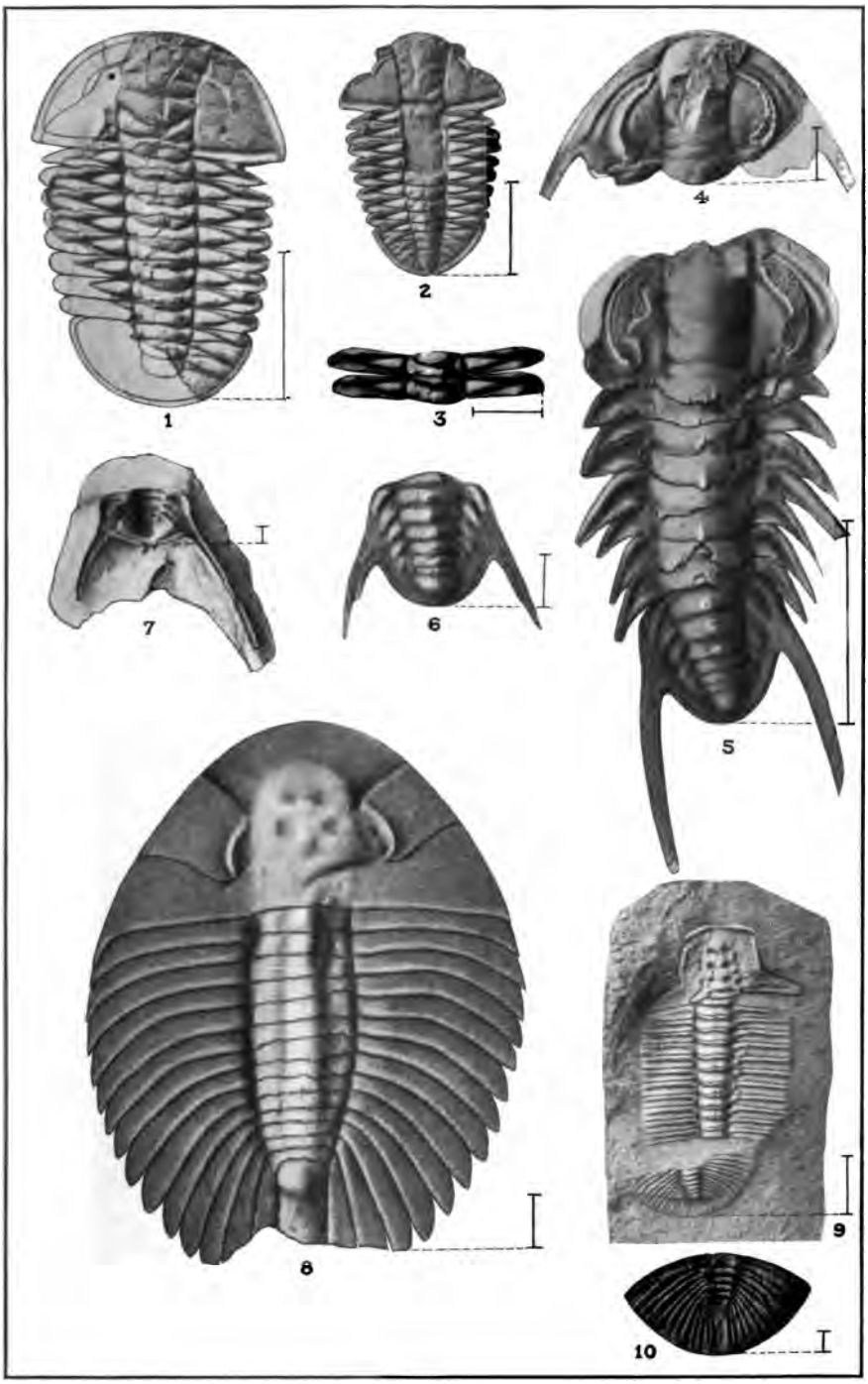
The specimen represented by figure 8 is from the Middle Cambrian Ogygopsis shale of the Stephen formation, 2,400 feet (731.5 m.) above the Lower Cambrian, on the northwest slope of Mt. Stephen, near Field, British Columbia.

Oryctocara geikiei, new genus and new species..... 23

FIG. 9. A nearly entire dorsal shield with the exception of the free cheeks. U. S. National Museum, Catalogue No. 53426.

10. Greatly enlarged matrix of a small pygidium. U. S. National Museum, Catalogue No. 53427.

The specimens represented by figures 9–10 are from the Spence shale of the Ute formation, near the base of the Middle Cambrian, in a ravine running up into Danish Flat from Mill Canyon, about 15 miles (9.37 km.) west of Montpelier, and 5 miles (3.12 km.) west-southwest of Liberty, Bear Lake County, Idaho.



CAMBRIAN TRILOBITES

DESCRIPTION OF PLATE 2

Page

Albertella helena, new genus and new species..... 19

FIG. 1. A nearly entire dorsal shield. U. S. National Museum, Catalogue No. 53410.

2. A pygidium retaining much of its natural form. The outer test is exfoliated about the margins. U. S. National Museum, Catalogue No. 53411.

3. A very small dorsal shield. U. S. National Museum, Catalogue No. 53409.

4. A large, broken dorsal shield. U. S. National Museum, Catalogue No. 53407.

5. A large cranidium. U. S. National Museum, Catalogue No. 53408.

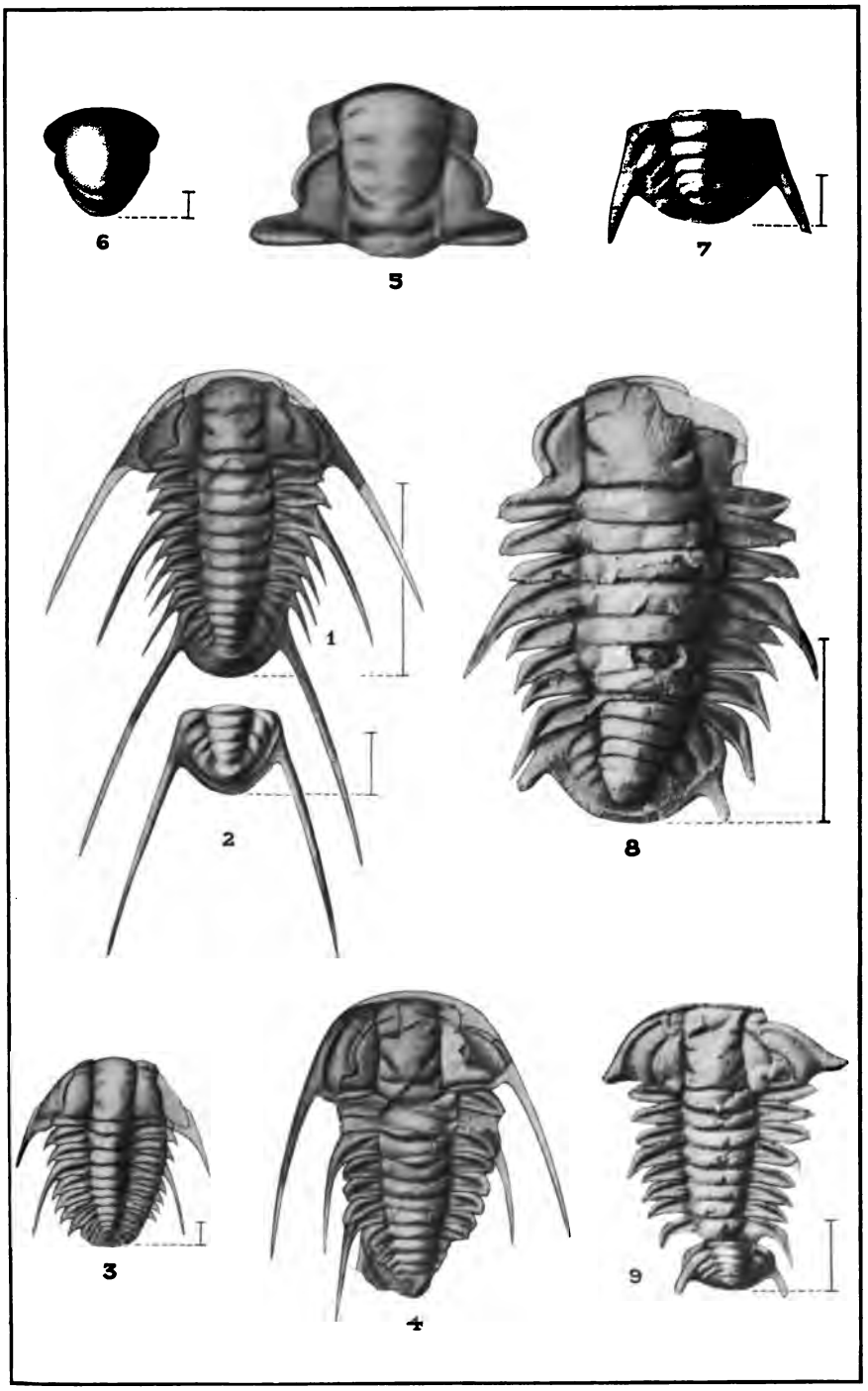
6. Hypostoma associated with this species. U. S. National Museum, Catalogue No. 53414.

7. A pygidium which compare with the pygidium of *A. bosworthi* on pl. 1, fig. 6. U. S. National Museum, Catalogue No. 53403.

8. A broken dorsal shield, broadened by compression. U. S. National Museum, Catalogue No. 53402.

9. A small dorsal shield. U. S. National Museum, Catalogue No. 53404.

The specimens represented by figures 1–5 are from Lower Cambrian shales on Gordon Creek, Ovando Quadrangle, Powell County, Montana, and those represented by figures 6–9 are from a drift block of Lower Cambrian shales found on the slopes of Mt. Bosworth, just north of the Canadian Pacific Railway, one mile (0.62 km.) east of Hector, British Columbia.



CAMBRIAN TRILOBITES

DESCRIPTION OF PLATE 3

Page

Zacanthoides idahoensis 26

FIG. 1. A large dorsal shield compressed in the shale. U. S. National Museum, Catalogue No. 53434.

2. A small dorsal shield with seven thoracic segments and three spines on each side of pygidium. U. S. National Museum, Catalogue No. 53437.

3. Small dorsal shield with adult characters. U. S. National Museum, Catalogue No. 53435.

4. Small dorsal shield with adult characters. U. S. National Museum, Catalogue No. 53436.

5. Dorsal shield of a very young individual with a strong spine on the axial lobe of the fifth segment. U. S. National Museum, Catalogue No. 53440.

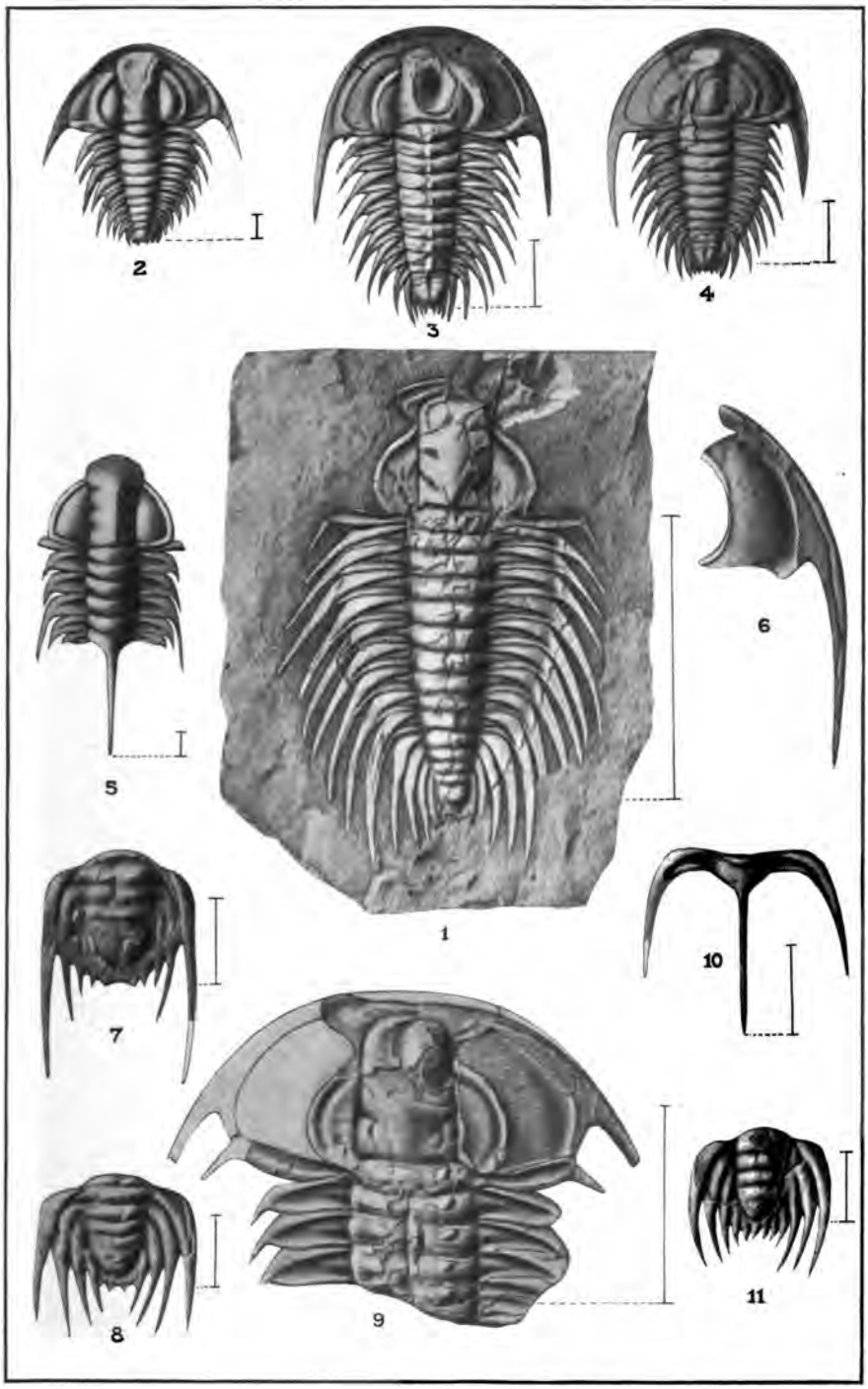
6. Large free cheek. U. S. National Museum, Catalogue No. 53432.

FIGS. 7, 8, and 11. Pygidia illustrating variations in spinose border. U. S. National Museum, Catalogue Nos. 53429, 53430, and 53431.

FIG. 9. Fragment of a large adult dorsal shield showing interocular spine, free cheek in position, and the lateral position of the genal spine on the free cheek. U. S. National Museum, Catalogue No. 53433.

10. Fifth thoracic segment with median spine. U. S. National Museum, Catalogue No. 53438.

The specimens represented by figures 1–10 are from the Spence shale of the Ute formation, near the base of the Middle Cambrian, in a ravine running up into Danish Flat from Mill Canyon, about 15 miles (9.37 km.) west of Montpelier, and 5 miles (3.12 km.) west-southwest of Liberty, Bear Lake County, Idaho.



CAMBRIAN TRILOBITES

DESCRIPTION OF PLATE 4

Page

Neolenus superbus, new species..... 36

FIG. 1. A nearly entire dorsal shield with the occipital spine broken off. U. S. National Museum, Catalogue No. 53383.

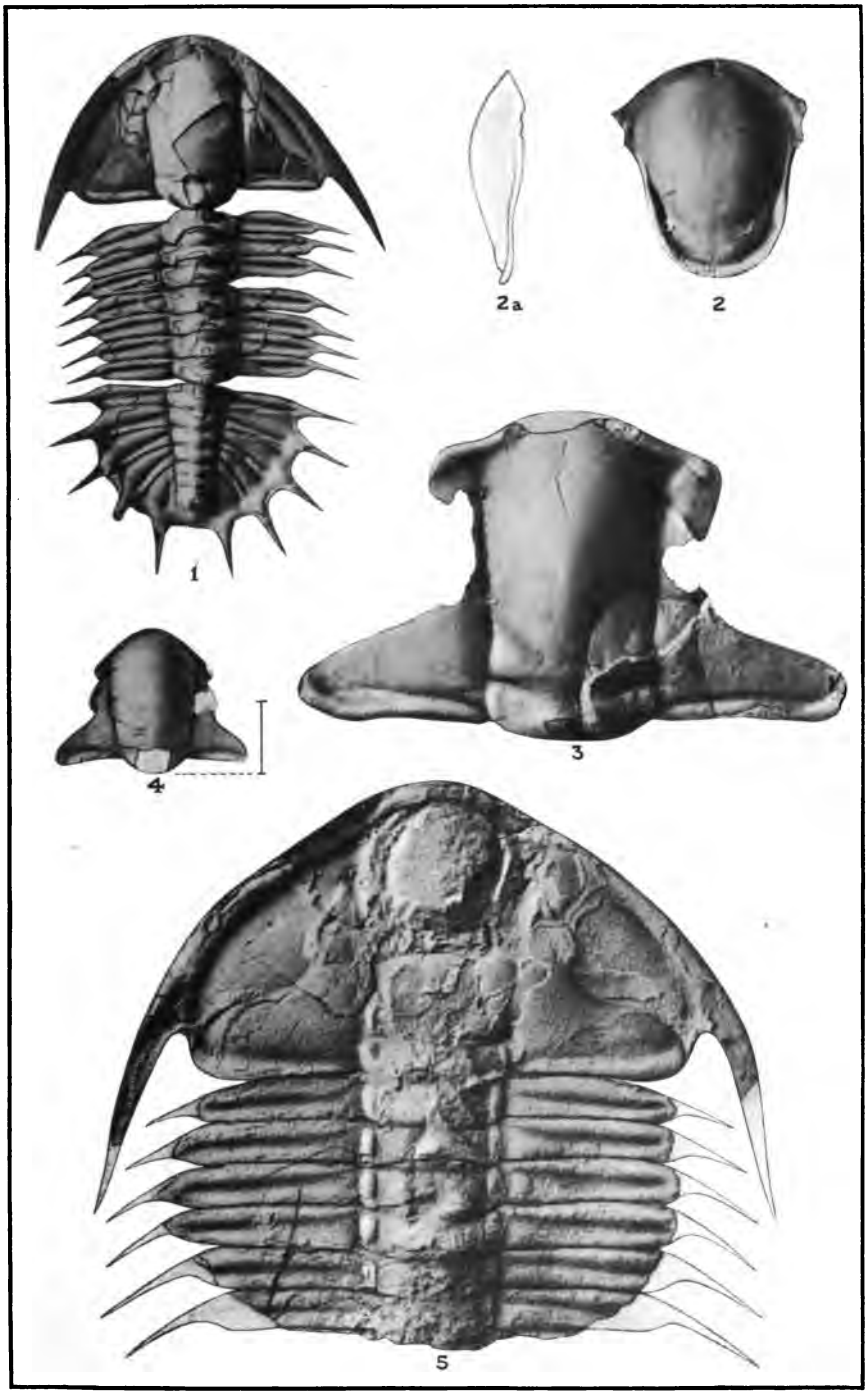
FIGS. 2 and 2*a*. Hypostoma associated with this species. U. S. National Museum, Catalogue No. 53381.

FIG. 3. Large compressed cranidium. U. S. National Museum, Catalogue No. 53384.

4. Small convex cranidium. U. S. National Museum, Catalogue No. 53382.

5. Portion of a large dorsal shield with well preserved outline of the cephalon. U. S. National Museum, Catalogue No. 53380.

The specimens represented by figures 1–5 are all from thin-bedded Middle Cambrian limestones of the Marjum formation, 2,140 feet (652.3 m.) above the top of the Lower Cambrian, in ridge on east side of Wheeler Amphitheater, east of Antelope Springs, House Range, Millard County, Utah.



CAMBRIAN TRILOBITES

DESCRIPTION OF PLATE 5

Page

Neolenus inflatus, new species..... 30

FIG. 1. A small nearly entire dorsal shield with the exception of the free cheeks. U. S. National Museum, Catalogue No. 53390.

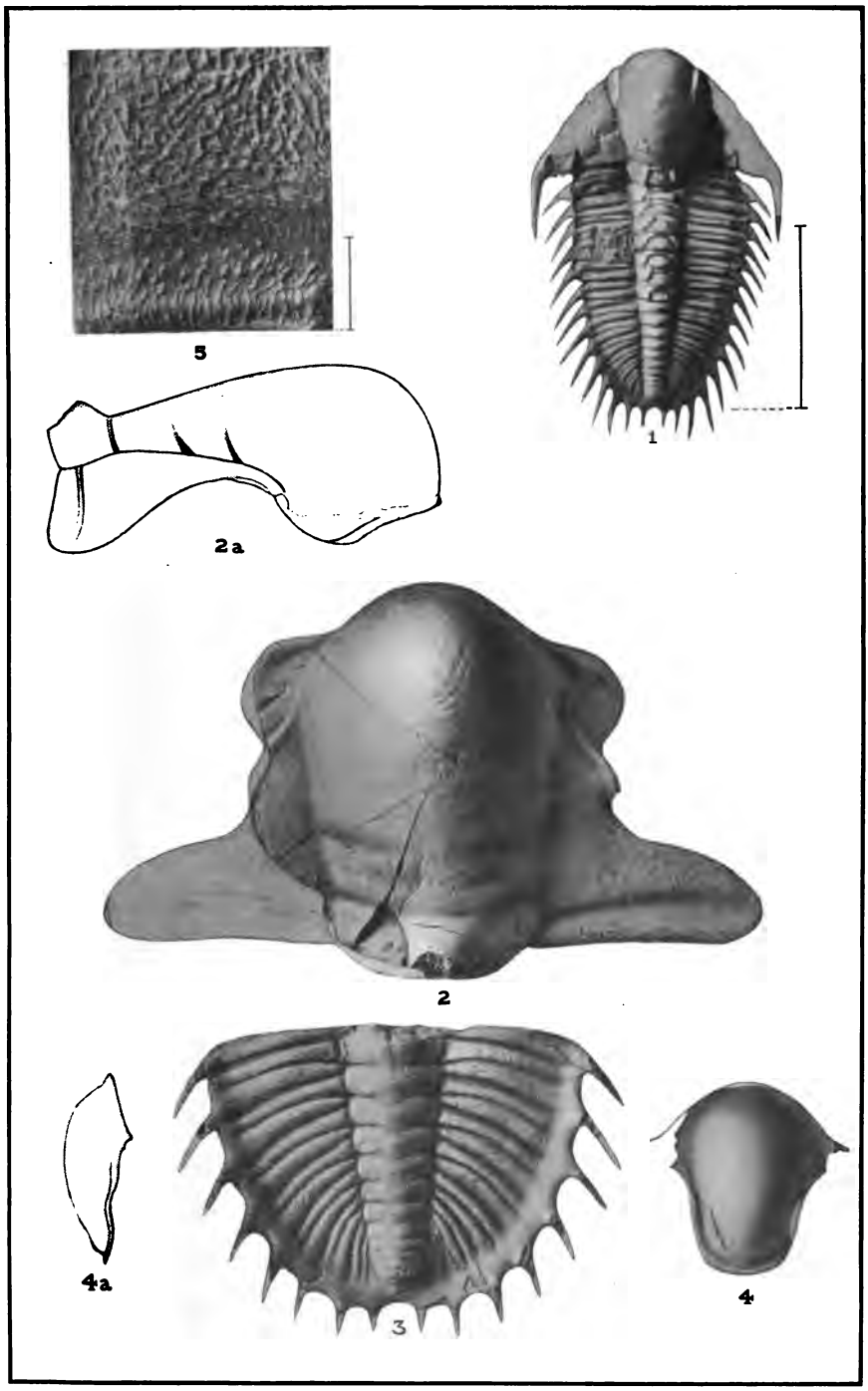
FIGS. 2 and 2*a*. A large cranidium. U. S. National Museum, Catalogue No. 53389.

FIG. 3. A characteristic pygidium. U. S. National Museum, Catalogue No. 53388.

FIGS. 4 and 4*a*. Associated hypostoma. U. S. National Museum, Catalogue No. 53386.

5. Enlargement of the exterior ornamentation of the surface of the fixed cheek back of the palpebral lobe. U. S. National Museum, Catalogue No. 53387.

The specimen represented by figure 1 is from thin-bedded Middle Cambrian limestones 2,300 feet (701 m.) above the Lower Cambrian; and the specimens represented by figures 2–5 are from thin-bedded Middle Cambrian limestones 2,140 feet (652.3 m.) above the top of the Lower Cambrian, both in the Marjum formation, in the ridge on east side of Wheeler Amphitheater, east of Antelope Springs, Millard County, Utah.



CAMBRIAN TRILOBITES

DESCRIPTION OF PLATE 6

Page

Neolenus intermedius, new species..... 34

FIG. 1. Cranidium and thorax; natural size. U. S. National Museum, Catalogue No. 53397.

2. Cranidium; natural size. U. S. National Museum, Catalogue No. 53394.

3. A pygidium with five marginal spines. Compare this pygidium with that of *Neolenus superbus* on pl. 4, fig. 1. U. S. National Museum, Catalogue No. 53398.

4. A pygidium with six marginal spines that is doubtfully referred to this species. U. S. National Museum, Catalogue No. 53392.

5. A small convex cranidium doubtfully referred to this species. U. S. National Museum, Catalogue No. 53395.

6. A small cranidium with a strong occipital node. U. S. National Museum, Catalogue No. 53396.

7. Hypostoma associated with this species. U. S. National Museum, Catalogue No. 53393.

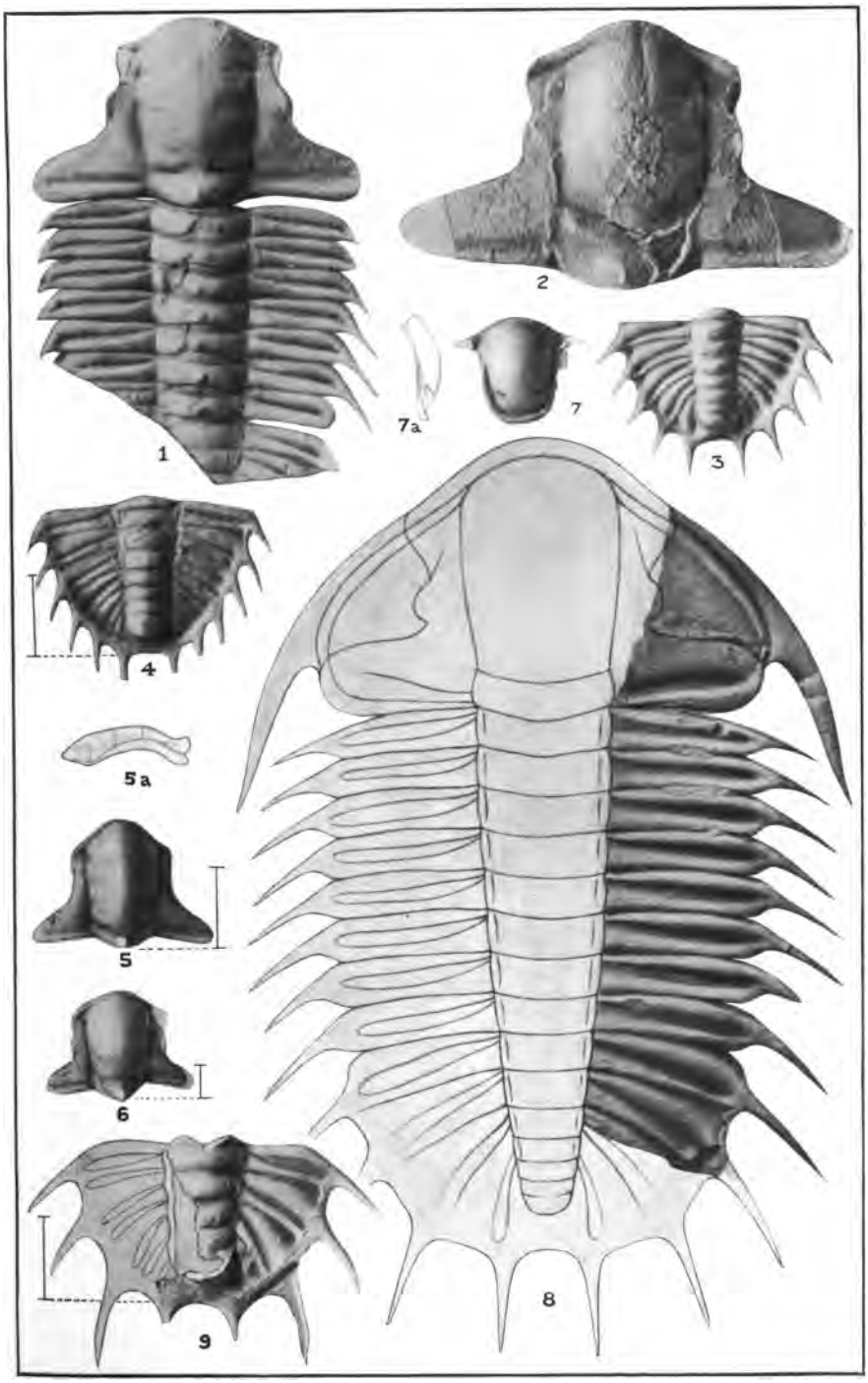
The specimen represented by figure 6 is from thin-bedded Middle Cambrian limestones 2,075 feet (632.5 m.) above the Lower Cambrian; that represented by figure 5 is from thin-bedded Middle Cambrian limestones 2,140 feet (652.3 m.) above the Lower Cambrian; and those represented by figures 1–4, and 7 are from thin-bedded Middle Cambrian limestones 2,300 feet (701 m.) above the Lower Cambrian; all in the Marjum formation, in ridge on east side of Wheeler Amphitheater, east of Antelope Springs, House Range, Millard County, Utah.

Neolenus intermedius pugio, new variety..... 35

FIG. 8. Fragment of a large dorsal shield with missing parts restored in outline. U. S. National Museum, Catalogue No. 53400.

9. A broken pygidium. U. S. National Museum, Catalogue No. 53401.

The specimens represented by figures 8 and 9 are from thin-bedded Middle Cambrian limestones of the Marjum formation, 2,300 feet (701 m.) above the Lower Cambrian, in ridge on east side of Wheeler Amphitheater, east of Antelope Springs, House Range, Millard County, Utah.



CAMBRIAN TRILOBITES

1908

SMITHSONIAN MISCELLANEOUS COLLECTIONS

PART OF VOLUME LIII

CAMBRIAN GEOLOGY AND PALEONTOLOGY

No. 3.—CAMBRIAN BRACHIOPODA: DESCRIPTIONS OF NEW GENERA AND SPECIES

WITH FOUR PLATES

BY

CHARLES D. WALCOTT

UNIVERSITY OF CALIFORNIA
DEPARTMENT OF
GEOLOGY AND MINERALOGY

No. 1810

CITY OF WASHINGTON

PUBLISHED BY THE SMITHSONIAN INSTITUTION

OCTOBER 1, 1908

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CORRECTIONS TO BE INSERTED IN SMITHSONIAN MISCELLANEOUS COLLECTIONS, VOLUME LIII.

NOTE.—This slip is so arranged that it may be torn apart and pasted in papers Nos. 1, 2, and 3.

CAMBRIAN GEOLOGY AND PALEONTOLOGY. WALCOTT.

No. 1.—NOMENCLATURE OF SOME CAMBRIAN CORDILLERAN FORMATIONS.

Page 2. The Mount Whyte formation which is placed in the Middle Cambrian on page 2 should be in the Lower Cambrian as indicated on page 4.

CAMBRIAN GEOLOGY AND PALEONTOLOGY. WALCOTT.

No. 2.—CAMBRIAN TRILOBITES.

Page 22. 17th line, strike out "Wolsey."
" 22. 18th line, (2.5 km.) should read (6.44 km.)
" 26. 4th and 5th lines,
" 30. 9th and 10th lines,
" 42. 43d and 44th lines,
" 46. 29th and 30th lines,
(9.37 km.) and (3.12 km.) should read (24.14 km.) and (8.05 km.), respectively.
" 33. 33d line,
" 35. 6th line,
" 35. 28th line,
" 38. 41st line,
(605–653.8 m.) should read (577.6–652.3 m.)
" 42. 27th line,
" 44. 27th line,
(0.62 km.) should read (1.61 km.)

CAMBRIAN GEOLOGY AND PALEONTOLOGY. WALCOTT.

No. 3.—CAMBRIAN BRACHIOPODA: DESCRIPTIONS OF NEW GENERA AND SPECIES.

Page 57. 32d line, "base of the Wolsey shale" should read "top of the quartzitic sandstones."
" 101. 18th line, strike out "Wolsey." The shale mentioned on these pages is not the equivalent of the Wolsey shale.

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By CHARLES D. WALCOTT

(With Four Plates)

This is the eighth paper resulting from the preliminary studies for Monograph 51 of the U. S. Geological Survey. I expect to use many new generic and specific names in lists of fossils occurring in geologic sections and in a forthcoming paper on the classification of the Brachiopoda, and think it is best to describe the fossils before using their names elsewhere.

The paper on the classification will be the last of the preliminary papers, as the monograph is now in the editor's hands and should appear in 1909.

The previous papers in this series are:

I. Note on the genus *Lingulepis.* American Jour. Sci., 4th ser., III, 1897, pp. 404–405.

II. Cambrian Brachiopoda: Genera *Iphidia* and *Yorkia,* with descriptions of new species of each, and of the genus *Acrothele.* Proc. U. S. National Museum, XIX, 1897, pp. 707–718.

III. Note on the brachiopod fauna of the quartzitic pebbles of the Carboniferous conglomerates of the Narragansett Basin, Rhode Island. American Jour. Sci., 4th ser., VI, 1898, pp. 327–328.

IV. Cambrian Brachiopoda: *Obolus* and *Lingulella,* with descriptions of new species. Proc. U. S. National Museum, XXI, 1898, pp. 385–420.

V. Cambrian Brachiopoda: *Obolella,* subgenus *Glyptias; Bicia; Obolus,* subgenus *Westonia;* with descriptions of new species. Proc. U. S. National Museum, XXIII, 1901, pp. 669–695.

VI. Cambrian Brachiopoda: *Acrotreta; Linnarssonella; Obolus;* with descriptions of new species. Proc. U. S. National Museum, XXV, 1902, pp. 577–612.

VII. Cambrian Brachiopoda, with descriptions of new genera and species. Proc. U. S. National Museum, XXVIII, 1905, pp. 227–337.

There are also a number of Cambrian brachiopoda described in two papers on the Cambrian faunas of China:

Cambrian Faunas of China. Proc. U. S. National Museum, XXIX, 1905, pp. 1–106.

Cambrian Faunas of China. Proc. U. S. National Museum, XXX, 1906, pp. 563–595.

Genus MICKWITZIA Schmidt [1888, p. 24]

MICKWITZIA OCCIDENS, new species

PLATE 7, FIGURE 1

There are only crushed and broken specimens of this shell. One of these shows that the apex of the ventral valve was a little above the posterior margin of the shell, very much as in *Mickwitzia pretiosa*. The outline of the valves appears to have been ovate to subcircular, with the ventral valve moderately convex. The shell is phosphatic or chitinous and built up of three principal layers. The outer layer is thin and thickly set with minute pustules or granules that give the surface a roughened appearance. When the outer layer is exfoliated, which is usually the case, the middle layer presents a smooth, shining surface that is marked by a few concentric striæ and numerous fine radiating striæ, between which many very minute punctæ occur. The inner layer shows minute, irregular, serpentine, rounded ridges, perforated by vertical canals or punctæ. An interior of a ventral valve shows the lines of advance of the anterolateral muscle scars. The largest shell indicated on the surface of the siliceous shale has a length and width of 12 mm.

This species and the generic reference is based on the character of the apex of the ventral valve and the structure and character of the shell.

FORMATION AND LOCALITY.—Lower Cambrian: (1) Near the base of the section, about 5,500 feet (1,676.4 m.) below the top of the Lower Cambrian, in shaly indurated sandstones, one mile (1.61 km.) east of the Saline Valley road, and 2 to 3 miles (3.22 to 4.83 km.) east-northeast of Waucoba Springs, Inyo County, California. (2) *Sandstones on small hill in the salt flat one mile (1.61 km.) northeast of Silver Peak Mill, Silver Peak quadrangle (U. S. G. S.), Esmeralda County, Nevada.*[1]

MICKWITZIA PRETIOSA, new species

PLATE 7, FIGURE 2

This species is founded on a single specimen of a ventral valve. It has a length of 7 mm.; width, 6.5 mm. Outline subcircular, slightly convex; apex curved over toward the posterior margin and projecting beyond it. False area short and obscure. Surface marked by radiating, raised lines, that at the front margin show six

[1] Where there is more than one locality, the one from which the type specimens come is italicised.

in a distance of two millimeters. Fine papillæ are thickly scattered over the surface. They have a tendency to follow concentric lines of growth on some portions of the shell, and on others they appear on low, narrow, serpentine ridges, as in *Mickwitzia monilifera* (Linnarsson) [1869, p. 344]. A few large punctæ are scattered here and there over the surface. Inner surfaces and layers of shell unknown.

This beautiful shell differs in the details of its surface from *M. monilifera;* it is also less convex and the apex is nearer the posterior margin.

FORMATION AND LOCALITY.—Lower Cambrian: Eophyton sandstone, at Lugnås, Vestergotland, Sweden.

Genus MICROMITRA Meek [1873, p. 479]

MICROMITRA HAYDENI, new species

PLATE 7, FIGURES 3 AND 3*a*

Ventral valve subconical, with a minute beak arching slightly over a strong, arched pseudodeltidium, which is about one-half as long as the height of the valve. Cardinal slope rounded; a slight angle is indicated by a line where the concentric surface striæ bend inward toward the pseudodeltidium across the narrow area; a sharp angle is formed where the convex pseudodeltidium rises abruptly from the area.

Dorsal valve moderately convex, most elevated at the small umbo just in advance of the marginal, minute beak; area very low and narrow and without trace of pseudodeltidium as far as now known.

Surface marked by fine, concentric, slightly undulating, thread-like striæ and a varying number of irregular, more or less interrupted, narrow, depressed, rounded, radiating ridges; these ridges are usually most numerous at the central portions of the valves. The concentric striæ extend across the narrow area and arch over the pseudodeltidium, where they are finer and crowded together, so that all the striæ between the apex and the front margin are compressed in about one-half the distance on the pseudodeltidium. The adult ventral valve is about 4.5 mm. in length by 5 mm. in width and 2.5 mm. in height, with a pseudodeltidium 1.3 mm. in length. A dorsal valve 2 mm. in length has a height of about 0.5 mm. at the umbo. The shell is rather thick for a species of this size and it is built up of several thin layers or lamellæ.

OBSERVATIONS.—*Micromitra haydeni* differs from the nearest related species, *M. sculptilis* (Meek) [1873, p. 479], in having a strong,

convex pseudodeltidium, less elevation of the ventral valve, and a thicker shell. *M. haydeni* occurs near the base of the Middle Cambrian and *M. sculptilis* about 2,000 feet (609.6 m.) higher in the section of the Cambrian rocks of Utah and southern Idaho.

The specific name is given in honor of Dr. F. V. Hayden, geologist and explorer, under whose charge the geology of this region was first studied.

FORMATION AND LOCALITY.—Middle Cambrian: Limestone of the Langston formation, just above the Cambrian quartzitic sandstone beds, north side of Two Mile Canyon, near its mouth, 2 miles (3.22 km.) southeast of Malad, Oneida County, Idaho.

MICROMITRA SCULPTILIS ENDLICHI, new variety

This form is represented by a single specimen of a ventral valve. The surface is similar to that of *Micromitra sculptilis* (Meek) [1873, p. 479], but the valve is more elongate, less elevated, and larger (5 mm. in diameter) than the specimens of the latter from the type locality.

FORMATION AND LOCALITY.—Upper Cambrian: Limestone 2 miles (3.22 km.) north of Aurum, Schell Creek Range, White Pine County, Nevada.

Subgenus IPHIDELLA Walcott [1905*a*, p. 304]

MICROMITRA (IPHIDELLA) LOUISE, new species

PLATE 7, FIGURES 4 AND 4*a*

In form this species is not unlike *Micromitra pealei* (Walcott) [1897*b*, p. 712] and the more elongate forms of *M.* (*Iphidella*) *pannula maladensis* (Walcott) [1905*a*, p. 306]. It differs from both species mentioned in its surface characters. In the latter respect it is more like *M.* (*I.*) *nyssa* (see p. 57), but the form of *M.* (*I.*) *louise* is more elongate and the apex of the ventral valve is nearer to the posterior margin; the shell also appears to have been thicker. The surface characters are exceedingly minute. Under a glass magnifying twenty diameters, the surface looks much like that of *M.* (*I.*) *pannula* (White) [1874, p. 6]. The largest ventral valve in the collection has a length of 7.5 mm. and a width of 7 mm.; elevation, 1 mm.

Micromitra (*Iphidella*) *louise* is the oldest brachiopod known from the Cambrian of the Canadian Rocky Mountains. In the Lakes Louise and Agnes section it is 3,100 feet (944.9 m.) below the summit of the Lower Cambrian and 2,750 feet (838.2 m.) below the

horizon which, on the basis of the associated faunas, is correlated with that at which *M.* (*I.*) *nyssa* occurs in Montana. It occurs in a fine, hard, dark gray, siliceous shale in association with *Hyolithes, Cruziana,* and a fragment indicating the free cheek of a trilobite.

FORMATION AND LOCALITY.—Lower Cambrian: Siliceous shale of the Lake Louise formation [Walcott, 1908*a*, p. 5], 3,100 feet (944.9 m.) below the summit of the Lower Cambrian, in cliff rising from the southwest shore of Lake Louise, south of Laggan, on the Canadian Pacific Railway, Alberta, Canada.

MICROMITRA (IPHIDELLA) NYSSA, new species

PLATE 7, FIGURE 5

Ventral valve subcircular in outline, with the posterior margin almost transverse; form depressed conical, with a minute beak incurving over the pseudodeltidium. The cardinal slope is compressed in all the specimens, but it indicates that there was an imperfectly defined narrow area. Pseudodeltidium, as far as can be determined, broad and short, with its lower margin broadly arched. Dorsal valve slightly convex, beak marginal. No traces of a false area or pseudodeltidium have been observed.

Surface marked by concentric striæ and lines of growth that are crossed obliquely by two sets of fine elevated lines. The crossing of the latter lines forms minute, shallow, rhomboidal pits, which give to the surface the appearance of a fine network. On the ventral valve the striæ cross the pseudodeltidium. Shell substance corneous.

OBSERVATIONS.—This is one of the largest shells of this genus. The ventral valve has a length of 11 mm. and a width of 13 mm. In form it resembles *Micromitra* (*Paterina*) *labradorica* (Billings) [1861*b*, p. 6], and in surface characters, *M.* (*Iphidella*) *ornatella* (Linnarsson) [1876, p. 25] and some varieties of *M.* (*I.*) *pannula* (White) [1874, p. 6].

FORMATION AND LOCALITY.—Middle Cambrian: About 200 feet (61 m.) above the base of the Wolsey shale, on ridge between Gordon and Young creeks, about half way between Gordon Mountain summit and Cardinal Peak, Ovando quadrangle (U. S. G. S.), Powell County, Montana.

Subgenus PATERINA Beecher [1891, p. 345]

MICROMITRA (PATERINA) STUARTI, new species

PLATE 7, FIGURES 8 AND 8*a*

Ventral valve subconical, with a minute beak arching slightly over a short pseudodeltidium. Cardinal slope with a rounded angle that extends from the beak to the postero-lateral margin and defines a very narrow, flattened area on each side of a high, triangular fissure that is covered for a short distance at the top by a very short, arched pseudodeltidium.

Dorsal valve rather strongly convex for a species of this genus; the highest part is at about the center of the shell, from where the slope is very slight to the beak and rather rapid to the front margin. Beak marginal above a low, broad arching of the posterior margin of the shell; area shown only by a very narrow margin where the shell bends toward the median line; no trace of a pseudodeltidium has been observed.

Surface marked by narrow, rounded, concentric thread-like striæ or ridges with short striæ between them. Shell substance corneous.

The average size of adult shells is 8 mm. long by about the same width.

OBSERVATIONS.—This is one of the larger species of the genus; it occurs quite abundantly in a compact, bluish-gray limestone in the lower portion of the Middle Cambrian terrane. *Micromitra* (*Paterina*) *superba* (Walcott) [1897*b*, p. 711] occurs 16 feet (4.8 m.) below and *M.* (*Iphidella*) *pannula* (White) [1874, p. 6] 70 feet (21.3 m.) below in the same section.

This fine shell has a short pseudodeltidium much like that of *M.* (*P.*) *logani* (Walcott) [1897, p. 711], but it differs in form and greater size; the same is true of *M.* (*P.*) *crenistria* (Walcott) [1897, p. 713]. It may be closely related to *M.* (*P.*) *labradorica utahensis* (Walcott) [1905, p. 306], but the specimens of the latter are too imperfect for close comparison of form.

The specific name is given for my son Benjamin Stuart, who assisted me in collecting the specimens during the summer of 1906.

FORMATION AND LOCALITY.—Middle Cambrian: Limestones of the Ute formation [Walcott, 1908*a*, p. 7], 185 feet (56.4 m.) above the Cambrian quartzitic sandstone beds, in Blacksmith Fork Canyon, about 8 miles (12.87 km.) above its mouth and 15 miles (24.14 km.) east of Hyrum, Cache County, Utah.

MICROMITRA (PATERINA) WAPTA, new species

PLATE 7, FIGURE 6

Shell large and thick for a species of this genus. Ventral valve depressed conical, with the apex above a narrow false area that is outlined by the abrupt curvature of the shell. As the shells usually occur compressed in the siliceous shale, the false area is concealed and the posterior slopes from the apex form a blunt angle at the apex. Dorsal valve transverse, moderately convex, with the posterior margin nearly straight and a little shorter than the greatest width of the valve; beak small, marginal; cardinal slope and false area unknown.

Surface marked by concentric, slightly irregular, rounded lines and ridges of growth that are grouped in bands of varying width; a few radiating striæ or lines occur on the central portions of one ventral valve; with a lens magnifying 20 diameters, an occasional roughness can be seen in reflected light on the surface of some of the concentric ridges.

OBSERVATIONS.—This is one of the largest species of the genus. One ventral valve has a length and breadth of 14 mm. and several are 9 to 11 mm. in diameter. It compares in size with *Micromitra* (*Iphidella*) *nyssa* (see p. 57), from the same geological horizon in Montana, but the latter has a reticulate exterior surface of the *M.* (*I.*) *pannula* (White) [1874, p. 6] type. It was at first thought that this species might be the old shells of *Acrothele colleni,* new species, but a careful comparison with the younger stages of growth of *M.* (*P.*) *wapta* shows that the latter has only indefinite traces of the highly ornate surface of *Acrothele colleni,* and that the apex of the ventral valve of *M.* (*P.*) *wapta* is imperforate and over the posterior margin and not on the general surface of the valve in advance of the margin, as in *Acrothele colleni.* The two species were found associated on Mount Bosworth. *M.* (*P.*) *wapta* is of the same type as *M.* (*P.*) *labradorica* (Billings) [1861*b,* p. 6], *M.* (*P.*) *prospectensis* (Walcott) [1884, p. 19], and *M.* (*P.*) *stissingensis* (Dwight) [1889, p. 145]. It differs from all in having more irregular, less definite threadlike concentric lines, and in the manner in which the striæ are assembled in ridges.

FORMATION AND LOCALITY.—Lower Cambrian: Drift block of siliceous shale supposed to have come from the Mt. Whyte formation [Walcott, 1908*a,* p. 4], south slope of Mount Bosworth, on the Continental Divide, one mile (1.61 km.) west of Stephen, on the Canadian Pacific Railway, British Columbia, Canada.

MICROMITRA (PATERINA) WILLIARDI, new species

PLATE 7, FIGURE 7

Iphidella major WALCOTT (in part), 1905, Proc. U. S. National Museum, XXVIII, p. 304. (Specimens now referred to *M. (P.) williardi* were included with the specimens representing *M. (P.) major* when this description was written.)

Ventral valve subconical, with the apex over the posterior third of the subcircular margin of the valve; false area narrow, but clearly defined by a rather sharp angle on the cardinal slopes that breaks the curvature of the shell a short distance from the margin of the pseudodeltidium; pseudodeltidium broad, convex, with its lower margin broadly arched, so as to leave a space between it and the general plane of the margin of the shell. Some specimens of the pseudodeltidium are uniformly rounded, in others there is a narrow groove extending from the apex to the base, and on some a very narrow faint ridge is indicated.

Dorsal valve slightly convex, transverse, and slightly rounded at the cardinal margin. No traces of a false area or pseudodeltidium have been observed.

The cast of the interior of the apex of the ventral valve shows a small apical callosity with two radiating grooves extending upward toward the front lateral margin of the shell.

Surface marked by very fine, strong, concentric, elevated striæ. A specimen 10 mm. in diameter shows seven of these elevated striæ in a distance of 1 mm.; the elevated striæ are crossed by very fine transverse striæ; the elevated striæ cross the false area parallel to its base and arch over the pseudodeltidium.

A ventral valve 10.5 mm. in diameter has a height of 2.5 mm.

OBSERVATIONS.—This species is closely related to *Micromitra (Paterina) superba* (Walcott) [1897*b*, p. 711]. It differs in having a longer pseudodeltidium, more finely elevated striæ on the surface, and a more sharply elevated apex to the ventral valve. It is the Lower Cambrian representative of *M. (P.) superba.*

The associated fossils are *Obolus smithi* (see p. 62), *Wimanella shelbyensis* (see p. 100), *Micromitra (Paterina) major* (Walcott) [1905*a*, p. 304], and numerous fragments of two or three species of *Olenellus.*

FORMATION AND LOCALITY.—Lower Cambrian: Montevallo argillaceous shale (1) 4 miles (6.44 km.) south of Helena; and (2) *.25 mile (.40 km.) northeast of Helena;* both in Shelby County, Alabama.

Genus OBOLUS Eichwald [1829, p. 274]

OBOLUS MEMBRANACEOUS, new species

PLATE 7, FIGURE 11

In size and outline this species is somewhat similar to *Obolus feistmanteli* (Barrande) [1879, pl. 106, figs. IV: 1–14; pl. 110, figs. VIII: 1–4], but in its very thin, almost membranaceous shell it differs from that species and all other species of the genus known to me. Seven specimens were collected from a shaly, compact limestone, all as casts. Remnants of the corneous shell are preserved which show it to have been very thin, and the interior casts show that it did not retain any impressions of the animal sufficiently strong to be impressed on the cast. A short, rather narrow cardinal area occurs on both the ventral and dorsal valves. Outer surface smooth, with a few lines of growth. The largest ventral valve has a length of 17 mm., with a width of 22 mm. A less distorted dorsal valve has the same length and width, 15 mm.

FORMATION AND LOCALITY.—Middle Cambrian: 4,250 feet (1295.4 m.) above the top of the Lower Cambrian and 860 feet (262.1 m.) below the Upper Cambrian, in shales of the Eldon formation [Walcott, 1908*a*, p. 3], at the north end of the amphitheater northwest of Mount Bosworth, on the Continental Divide, north of the Canadian Pacific Railway, British Columbia, Canada.

OBOLUS PARVUS, new species

PLATE 7, FIGURES 10 AND 10*a*

Shell small, rarely over 2.5 mm. in diameter, moderately convex, nearly semicircular in outline. Ventral valve a little longer than wide and with the umbo curving gently to the minute marginal beak. Dorsal valve a little wider than long and with apex marginal. Surface marked by minute concentric striæ of growth and an exceedingly fine network of irregular lines, that, with a lens magnifying 20 diameters, gives it the appearance of the surface of *Lingulella* (*Lingulepis*) *longinervis* (Matthew) [1903, p. 133]. Nothing is known of the interior of the valves.

OBSERVATIONS.—This small shell occurs in great abundance with *Micromitra* (*Paterina*) *wapta* (see p. 59), *Wimanella simplex* (see p. 101), *Albertella helena* Walcott [1908*b*, p. 19], and other fossils of the fauna of the upper portion of the Lower Cambrian terrane in the Canadian Rocky Mountains. In form it resembles *Obolus mini-*

mus Walcott [1905*a*, p. 325] from China, but it differs in having a less elongate ventral valve and in its peculiar surface.

FORMATION AND LOCALITY.—Lower Cambrian: (1) 1,250 feet (381 m.) above Lake Agnes, in the shales of the Mt. Whyte formation [Walcott, 1908*a*, p. 4], on the north slope of Mt. Whyte, about 4 miles (6.44 km.) south of Laggan, on the Canadian Pacific Railway, Alberta; and (2) *drift block of shale supposed to have come from the Mt. Whyte formation, on the south slope of Mount Bosworth, on the Continental Divide, one mile (1.61 km.) west of Stephen, on the Canadian Pacific Railway, British Columbia, Canada.*

OBOLUS SMITHI, new species

PLATE 7, FIGURES 9 AND 9*a*

General form broadly ovate, with the ventral valve obtusely acuminate and the dorsal valve subcircular, slightly transverse; convexity apparently moderate, judging from the specimens as they occur slightly flattened out in the calcareous shales. The shell was relatively strong and formed of a number of thin layers or lamellæ that, toward the outer edge of the valve, were more numerous and gave a scaly appearance to the margins of the old shells.

Surface marked by concentric lines of growth and numerous very fine, slightly irregular, undulating, concentric ridges upon which numerous very minute papillæ occur, giving the surface, under a strong magnifying power, the appearance of being minutely granular.

A ventral valve 6 mm. in length has a width of 6.75 mm. A slightly larger dorsal valve 7.5 mm. in length has a width of 8 mm.

As shown in the cast, the area of the ventral valve is very short and divided by a relatively strongly marked, narrow pedicle furrow, the edges of which were elevated slightly above the general plane of the area. The cast of the interior shows that the visceral area was continued by a slight, narrow median ridge; the main vascular sinuses extended rather directly forward from the umbo nearly to the front of the shell, separating very gradually and bounding the interior third of the valve. Nothing has been observed of the muscle scars.

The cast of the dorsal valve shows that it had a very short area that extended well out on the cardinal slopes; that a low central ridge extended a little more than half the length of the shell and was continued by a slight, narrow median ridge; the main vascular sinuses extend directly and obliquely forward well toward the front of the shell in about the same relative position as in the ventral

valve; the position of the transmedian and anterior-lateral muscle scars is indicated about half way between the main vascular sinuses and the postero-lateral margin of the valve.

OBSERVATIONS.—This species is characterized by its finely granular surface, short cardinal area, and relatively thick shell. It has the general form of *Obolus lamborni* (Meek) [1871, p. 185] and *Obolus willisi* (Walcott) [1898*b*, p. 418]. It differs from both of these species in having a granulated surface and shorter cardinal area. It is a Lower Cambrian form, but appears to be represented in the Middle Cambrian by *Obolus willisi* and in the Upper Cambrian by *Obolus lamborni.* The associated fossils are *Wimanella shelbyensis* (see p. 100), *Micromitra* (*Paterina*) *major* (Walcott) [1905, p. 304], *Micromitra* (*Paterina*) *williardi* (see p. 60), and numerous fragments of two or three species of *Olenellus.*

The specific name is given in honor of Prof. E. A. Smith, State Geologist of Alabama.

FORMATION AND LOCALITY.—Lower Cambrian: Montevallo shale (1) 4 miles (6.44 km.) south of Helena; and (2) *along road just north of Buck Creek, .125 mile* (*.20 km.*) *northeast of Helena;* both in Shelby County, Alabama.

OBOLUS TETONENSIS LEDA, new variety

This is the Upper Cambrian representative of *Obolus tetonensis* Walcott [1901, p. 684] of the Middle Cambrian of the Teton Mountains. Stratigraphically it occurs over 2,000 feet (609.6 m.) higher in the Cambrian section of the House Range, and the localities are 400 miles (644 km.) apart. The variety *leda* differs from the species in having more numerous, fine, thread-like striæ and in the fact that the ventral valve is usually more obtuse in old shells.

FORMATION AND LOCALITY.—Upper Cambrian: 1,945 to 1,975 feet (592.8 to 601.9 m.) above the Middle Cambrian and 1,340 to 1,370 feet (408.4 to 417.6 m.) below the top of the Upper Cambrian, in the siliceous limestones of the Notch Peak formation [Walcott, 1908*a*, p. 9], on the slopes of Notch Peak, 5 miles (8.05 km.) southwest of Marjum Pass, House Range, Millard County, Utah.

OBOLUS WORTHENI, new species

PLATE 7, FIGURE 17

General form subcircular, with the ventral valve very obtusely acuminate and the dorsal valve slightly transverse, both valves slightly convex; ventral valve with the beak at the posterior margin, which rises slightly from the general plane of the margin of the valve; the minute beak of the dorsal valve is at the posterior margin.

Surface marked by sharp, fine, concentric striæ and fine imbricating lines of growth; on some shells low, irregular, more or less obscure and interrupted radiating ridges occur. Shell of medium thickness and built up of several layers or lamellæ. The average diameter of the valves is 3 mm.

The interior of the ventral valve shows a short, flat area divided midway by a narrow pedicle furrow; the visceral area, which is about one-third the length of the valve, is shown only in outline; the main vascular sinuses are strong and situated about midway between the median line and the lateral margins of the valve; the surface outside the visceral area in both valves is marked by fine concentric furrows and large scattered punctæ, much like those of *Obolus* (*Westonia*) *escasoni* (Matthew) [1901, p. 270]. The interior of the dorsal valve has a short area with a broad pedicle groove; strong, curved main vascular sinuses extend from beneath the area well toward the front of the valve; they are subparallel to the margin and are situated about one-third the distance from the margin to the median line of the valve; the visceral area is outlined in about one-half the length of the valve; a narrow deep sinus extends from each side of the anterior end and then curves outward to the front margin.

OBSERVATIONS.—This shell was at first thought to be the young of *Obolus tetonensis* Walcott [1901, p. 684], but with the finding of a good series it was found to have a nearly circular ventral valve instead of subacuminate, as in *O. tetonensis,* and it is less convex in the same character of matrix. In form *Obolus wortheni* resembles *Obolus discoideus* (Hall and Whitfield) [1877, p. 205], but it differs in being more circular in outline and in having a thinner shell.

FORMATION AND LOCALITY.—Upper Cambrian: Limestone of the St. Charles formation [Walcott, 1908*a*, p. 6] about 250 feet (76.2 m.) above the Middle Cambrian, on the north side of Two Mile Canyon, near its mouth, 2 miles (3.22 km.) southeast of Malad, Oneida County, Idaho.

FORDINIA, new subgenus of OBOLUS

This subgenus of *Obolus* is proposed for species having a *Lingulella*-like outline and form with the development of a tendency to form a platform or thickening in the valves in connection with the attachment of the muscles in the ventral valve, and a thickening in the posterior portion of the dorsal valve back of the central muscle scars. The type of the subgenus, *O.* (*F.*) *perfectus* (see p. 65), has these characters well developed. Another species, *O.* (*F.*) *bellulus* (Walcott) [1905*a*, p. 323], has the cardinal area of the ventral valve more united with the visceral area than it is in *O.* (*F.*) *per-*

fectus and the raised area in the dorsal valve is much smaller. In *O.* (*F.*) *gilberti* (see below) the thickened areas are much smaller than in the other two species. These three species appear to be forms intermediate between *Obolus* and *Elkania*.

TYPE.—*Obolus* (*Fordinia*) *perfectus*, new species.

OBOLUS (FORDINIA) GILBERTI, new species

PLATE 7, FIGURES 15 AND 15*a*

This shell was first thought to belong with *Dicellomus politus* (Hall) [1861, p. 24]. It differs from that species in the character of the interior of the dorsal valve and in the narrowing of the umbo as it merges into the apex. The nearest related species is *Obolus* (*Fordinia*) *bellulus* (Walcott) [1905*a*, p. 323]. It differs from the latter in being more convex and in the narrowing of the umbo toward the apex.

The average size of the ventral valve is from 4 mm. to 5 mm. in length by 3 mm to 4 mm. in width. The dorsal valve is a little shorter than the ventral.

The generic reference is based on the interior of the dorsal valve, which is similar to that of *O.* (*F.*) *bellulus*.

FORMATION AND LOCALITY.—Middle Cambrian: About 3,000 feet (914.4 m.) above the top of the Lower Cambrian and 1,400 feet (526.7 m.) below the Upper Cambrian, in gray, more or less thin-bedded limestones of the Marjum formation [Walcott, 1908*a*, p. 10], south side of Marjum Pass, in cliff southeast of divide, House Range, Millard County, Utah.

OBOLUS (FORDINIA) PERFECTUS, new species

PLATE 7, FIGURE 16

General form elongate oval-biconvex; beaks marginal. Surface marked by concentric lines and striæ of growth that gather irregularly in small ridges on the anterior two-thirds of adult shells; very fine, obscure, radiating lines are preserved on some specimens of the outer surface. A shallow, narrow, median sinus occurs on each valve on which the striæ arch slightly backward. Substance of shell apparently calcareo-corneous. The shell is strong and built up of numerous layers or lamellæ that, except toward the beaks, are oblique to the outer layer.

Ventral valve broad ovate, with a rather blunt subacuminate beak; very young shells are broad oval in outline. Area short, and on the

plane of the edges of the valve; it is divided midway by a narrow pedicle furrow that interrupts the transverse striæ of growth.

Dorsal valve a little shorter and more rounded at the beak; area short and marked by transverse striæ of growth; both valves moderately convex.

The interior of the ventral valve shows what appears to be a short continuation of the cardinal area forward into the valve before the slope into the visceral cavity; it is as though an area with lines of growth was added to the reversed area of the ventral valve of *Elkania desiderata* (Billings) [1862, p. 69]. The front margin of the area merges in *Obolus* (*Fordinia*) *perfectus* into the thicker shell back of the visceral cavity, much as in *Obolus* (*F.*) *bellulus* (Walcott) [1905*a*, p. 323]. The pedicle furrow extends forward from the posterior margin across the true area and its anterior extension to the visceral cavity. The visceral area is bordered by two ridges that diverge from the sides of the pedicle furrow and extend forward about one-third the length of the valve; these ridges widen toward the front, and where they terminate there appear to be two or three minute muscle scars corresponding to the outside and middle laterals and central scars of *Obolus;* outside of the ridge there is a furrow that was probably occupied by the main vascular canal, and, beyond, two narrow elongate spaces in which the transmedian and anterior lateral muscle scars appear to be situated; all the furrows head back against the thickened shell in front of the cardinal area; the surface of the interior of the valve is marked by concentric lines and very fine radiating striæ.

The dorsal valve has a short, strong median ridge in front of the cardinal area, and well toward the center of the valve a narrow, sharp median ridge; on each side of the latter, where it begins posteriorly, the small, oval, central muscle scar occurs, and, at its anterior end, the two elongate, oval anterior-lateral scars that are larger than the centrals; on the thickened postero-lateral portions of the valve the transmedian and outside and middle lateral muscle scars occur close to the outer margin. The surface of the visceral cavity is smooth, but in front of it the minute, irregular vascular markings are very ornate; a few radiating striæ also occur.

The two interiors described are unusually distinct; usually the various parts and scars are more or less obscure.

OBSERVATIONS.—This species approaches *Obolus* (*Fordinia*) *gilberti* (see p. 65) more nearly than any other species of the genus. It differs in the presence of the sinus in both valves; in being less convex; in its less pointed beak, and in its strongly marked interior.

It occurs over 1,000 feet (304.8 m.) higher up in the section of the Middle Cambrian limestones than *O.* (*F.*) *gilberti.* The interior of its ventral valve is somewhat like that of *O.* (*F.*) *bellulus* (Walcott) [1905, p. 323], but it differs from that and all species of *Fordinia* in having in both valves a cardinal area that has not been merged into the reversed area of the ventral valve as in the other species referred to *Fordinia.*

FORMATION AND LOCALITY.—Middle Cambrian: About 3,750 feet (1,143 m.) above the top of the Lower Cambrian and 650 feet (198.1 m.) below the Upper Cambrian, in the shaly limestones of the Weeks formation [Walcott, 1908*a*, p. 10], north side of Weeks Canyon, 3.5 miles (5.63 km.) south of Marjum Pass, House Range, Millard County, Utah.

Subgenus WESTONIA Walcott [1901, p. 683]

OBOLUS (WESTONIA) DARTONI, new species

PLATE 7, FIGURE 14

This species has the general form and convexity of *Obolus* (*Westonia*) *euglyphus* (Walcott) [1898*b*, p. 402], but it differs in the dorsal valve being narrower posteriorly. The surface of the two species differs very much, that of *O.* (*W.*) *dartoni* being of the *O.* (*Westonia*) *ella* (Hall and Whitfield) [1877, p. 232] type and not like that of *O.* (*W.*) *euglyphus.* From *O.* (*W.*) *ella* this species differs in being more elongate in outline and in having the surface more clearly marked by the crossing of the minute ridges; these ridges are slightly irregular and curve from near the umbo obliquely across the shell toward the lateral and front margins. The largest ventral valve has an indicated length of from 12 to 15 mm.; width, 9 mm.

The specific name is given for Mr. N. H. Darton, of the U. S. Geological Survey, who collected the specimens.

FORMATION AND LOCALITY.—Middle Cambrian: Sandstones just above the granite, west of Garfield Peak, 50 miles (80.47 km.) west of Casper, Natrona County, Wyoming.

OBOLUS (WESTONIA) ELLA ONAQUIENSIS, new variety

This variety is represented by a number of more or less imperfect specimens that at first sight might be placed with *Obolus* (*Westonia*) *ella* (Hall and Whitfield) [1877, p. 232], but the character of the surface clearly distinguishes the two forms. In typical forms of *O.* (*W.*) *ella* the transverse striæ are more regular, while in this variety

they are in the form of sharp, finely zigzag, transverse striæ much like the shells from the Big Horn Mountains of Wyoming. This surface is formed by the interruption of very fine, sharp ridges that curve from the umbo outward toward the sides and front of the shell like engine-turning striæ on a watch-case.

FORMATION AND LOCALITY.—Middle Cambrian: Shales about 400 feet (122 m.) above the quartzitic sandstones, from high peak southwest of Lookout Pass, Onaqui Range, west of Vernon, Tooele County, Utah.

OBOLUS (WESTONIA) ELONGATUS, new species

PLATE 7, FIGURE 12

General form elongate oval, with the ventral valve acuminate and the dorsal valve elongate oval. Convexity unknown, as the shells are all flattened by compression.

The outer surface is marked by fine concentric lines of growth crossed by a series of finely denticulated, imbricating lines that start on each cardinal slope and extend obliquely forward across the median line, and then curve out toward the sides of the shell; minute rhomboidal spaces are formed over the posterior and central portions of the shell by the crossing of the oblique lines; the denticulated margin faces forward and is seen only on the thin epidermal layer, while the general system of oblique lines shows on both the outer layer and the next inner layer of the shell.

The shell is built up of several thin layers or lamellæ. The largest specimen of the ventral valve has a length of 9 mm.; width, 5 mm.; a dorsal valve 6 mm. long has a width of 4 mm. Nothing is known of the interior of these valves.

This is a more elongate species than *O.* (*W.*) *bottnica* (Wiman) [1902, p. 51] and *O.* (*W.*) *finlandensis* (Walcott) [1902, p. 611]. The oblique surface lines have the same general direction as those of the latter species, but they are finely denticulated on their front margin and cross at the center at a greater angle.

FORMATION AND LOCALITY.—Middle Ordovician: Gray, siliceous shales just below a band of quartzitic sandstones, probably corresponding in position to the upper part of the Simpson formation of the Oklahoma section; Wasatch Canyon, 5 miles (8.05 km.) north of Brigham, Box Elder County, Utah.

OBOLUS (WESTONIA) NOTCHENSIS, new species

PLATE 7, FIGURE 13

This species is represented by two specimens of the ventral valve that have the general outline of *Lingulella ampla* (Owen) [1852, p. 583]. The exterior surface is marked by concentric lines of growth and transverse, irregular, imbricating lines much like those of *O.* (*W.*) *stoneanus* (Whitfield) [1882, p. 344] and *O.* (*W.*) *iphis* Walcott [1905*a*, p. 336]. The form of the valve differs from that of the latter species.

The largest specimen has a length of 11 mm., with a maximum width of 9 mm.

FORMATION AND LOCALITY.—Lower Ordovician: Thin-bedded, bluish-gray limestone; at the summit of Notch Peak, House Range, Millard County, Utah.

OBOLUS (WESTONIA) WASATCHENSIS, new species

PLATE 8, FIGURES 1 AND 1*a*

This species is founded on some large shells that differ from *Obolus* (*Westonia*) *ella* (Hall and Whitfield) [1877, p. 232] in attaining a larger size and greater proportional width and in having the surface marked by radiating lines that extend from the umbo with a gentle curvature toward the sides and front of the shell, so as to terminate at right angles to the margin, very much as in *O.* (*W.*) *finlandensis* Walcott [1902, p. 611].

In the Blacksmith Fork section of the Middle Cambrian terrane, in the Wasatch Mountains of northern Utah, *O.* (*W.*) *wasatchensis* occurs 1,590 feet (484.6 m.) higher in the section than *O.* (*W.*) *ella*.

FORMATION AND LOCALITY.—Middle Cambrian: (1) Shales about 950 feet (289.6 m.) above the Cambrian quartzitic beds, 2 miles (3.22 km.) southeast of Muskrat Spring, on the northwest face of Grantsville Peak, Stansbury Range, Tooele County; (2) about 1,700 feet (518.2 m.) above the Cambrian quartzitic beds; (3) about 2,300 feet (701 m.) above the Cambrian quartzitic beds; and (4) *a drift block supposed to have come from the horizon of* (2); all three in Wasatch Canyon, east of Lakeview Ranch, 5 miles (8.05 km.) north of Brigham, Box Elder County; (5) about 1,500 feet (457.2 m.) above the Cambrian quartzitic beds, one mile (1.61 km.) northwest of Geneva (Copenhagen), east of Brigham, Box Elder County; (6) about 3,150 feet (960.1 m.) above the top of the Cam-

brian quartzitic sandstones and 1,050 feet (320 m.) below the Upper Cambrian in thin-bedded limestones of the Bloomington formation [Walcott, 1908*a*, p. 7]; and (7) *about 2,100 feet (640.1 m.) above the top of the Cambrian quartzitic sandstones and 2,090 feet (637 m.) below the Upper Cambrian in the shales of the Bloomington formation;* both about 8 miles (12.87 km.) above the mouth of Blacksmith Fork, and 15 miles (24.14 km.) east of Hyrum, Cache County; all in Utah. (8) About 2,000 feet (609.6 m.) above the Cambrian quartzitic beds and 1,200 feet (365.8 m.) below the Upper Cambrian, in the shales of the Bloomington formation, on the south side of Two Mile Canyon near its mouth, 2 miles (3.22 km.) southeast of Malad, Oneida County, Idaho.

MICKWITZELLA, new subgenus of OBOLUS

Obolus (*Thysanotos*) MICKWITZ, 1896, Mem. Acad. Imp. Sci., St. Pétersbourg, 8th ser., IV, No. 2, pp. 194–195. (Characterized in German as a new subgenus; see below for translation.)

Obolus (*Thysanotus*) Mickwitz, WALCOTT, 1901, Proc. U. S. National Museum, XXIII, p. 683. (Characterized.)

Not *Thysanota* ALT., 1860.

ORIGINAL DESCRIPTION BY MICKWITZ.—"The subgenus *Thysanotos,* containing a single species, *O. siluricus* Eichwald, differs from the Cambrian subgenera *Euobolus* and *Schmidtia* mainly by the fringed anterior border of the growth lamellæ of its valves and by the concentric striation arranged parallel to the posterior edge of these lamellæ—two features that point to a peculiar organization of the edge of the mantle. The last-mentioned peculiarity appears also in the subgenus *Acritis.*"

TYPE.—*Obolus siluricus* Eichwald [1843, p. 7].

Genus LINGULELLA Salter [1866*b*, p. 333]

LINGULELLA BUTTSI, new species

PLATE 8, FIGURE 6

General form elongate ovate, with the ventral valve bluntly acuminate and the dorsal valve a little more rounded on the posterior margin; both valves rather strongly convex. The greatest convexity of the dorsal valve is at the umbo, and of the ventral valve along the central section. A ventral valve 12 mm. in length has a convexity of 2 mm., and a dorsal valve 8 mm. long arches 1.75 mm. above the plane of the margin. A narrow, median, slightly flattened, almost concave space, that extends from the apex to the front margin, occurs on the dorsal valve. The exterior surface of the shell is dull

dark bluish-gray and the inner layers shiny bluish-black. The outer surface is marked by concentric striæ, and lines of growth with a few indistinct radiating striæ; the striæ on the dorsal valve bend slightly backward where they cross the median, flattened space. The inner layers have many concentric striæ; also numerous fine radiating striæ. The shell is built up of several layers or lamellæ, so as to be strong in the umbonal region and thin toward the edges.

The largest ventral valve in the collection has a length of 12 mm. and a maximum width of 9.5 mm. at the anterior third of its length; a dorsal valve 10 mm. long has a width of 7 mm.

A partially exfoliated ventral valve indicates the presence, on each side of the visceral area, of a strong ridge somewhat similar to that in *Lingulella acutangula* (Roemer) [1849, p. 20].

OBSERVATIONS.—This fine shell has the general outline of the group of small shells of which *Lingulella ferruginea* Salter [Salter and Hicks, 1867, p. 340] is typical. It differs from them in its large size and strong shell. All of the larger species of *Lingulella* are either more acuminate or broader in outline.

The material was collected by Mr. Charles Butts, of the United States Geological Survey, and I take pleasure in naming the species after him.

FORMATION AND LOCALITY.—Upper Cambrian: (1) Limestones in cut on Louisville and Nashville Railroad, near Woodstock; and (2) *limestones near Kimbrel;* both in Bibb County, Alabama.

LINGULELLA TEXANA, new species

PLATE 8, FIGURE 5

This is a small but distinctly marked species, represented by two dorsal valves occurring in the Middle Cambrian limestones of central Texas. The dorsal valves are oval and quite strongly convex. The shell appears to have been rather thick, and the outer surface is marked by strong, radiating striæ, which are characteristic of the species. The striæ are crossed by fine, concentric striæ and lines of growth. The position of the muscle scars and the size and character of the area are shown by fig. 5.

FORMATION AND LOCALITY.—Middle Cambrian: (1) Limestone near Honey Creek; and (2) *limestone near Morgan Creek;* both in Burnet County, Texas. (3) Sandstones of Potosi formation, on Flat River, Missouri.

Subgenus LINGULEPIS Hall [1863, p. 129]

LINGULELLA (LINGULEPIS) ACUMINATA SEQUENS, new variety

PLATE 8, FIGURE 4

Glossina acuminata HALL and CLARKE [not Conrad], 1892, Eleventh Ann. Rept. State Geologist New York for 1891, pl. 1, figs. 10, 11. (No text reference.)

Lingula (*Glossina*) *acuminata* HALL and CLARKE [not (Conrad)], 1892, Nat. Hist. New York, Paleontology, VIII, Pt. 1, pl. 1, figs. 1, 2. (No text reference. Figures 1 and 2 are copied from pl. 1, figs. 10 and 11, of the preceding reference.)

This variety differs from *Lingulella* (*Lingulepis*) *acuminata* (Conrad) [1839, p. 64] in being somewhat less attenuate in its ventral valve and in having the cardinal slope of the ventral valve straight instead of gently incurved. It occurs at a slightly higher geologic horizon than *L.* (*L.*) *acuminata* and appears to be a form derived from that species.

Judging from Messrs. Hall and Clarke's illustrations [1892*a*, pl. 1, figs. 10 and 11], they had representatives of this variety of *L.* (*L.*) *acuminata* and mistook them for the form illustrated by Hall [1847, p. 9] as *Lingula acuminata*. That figure represents a typical form of *L.* (*L.*) *acuminata* and is not the variety illustrated by Hall and Clarke in 1892.

The specimens illustrated by Messrs. Hall and Clarke are given as from the Calciferous sandstone in Saratoga County, New York. The specimen which I have taken as the type of this variety is from Division A of the Beekmantown formation.

FORMATION AND LOCALITY.—Ordovician: Beekmantown formation, Division A; quarry near the northwest suburb of Ticonderoga, Essex County, New York.

NEOBOLUS Waagen [1885, p. 756]

Neobolus WAAGEN, 1885, Mem. Geol. Survey India, Paleontologia Indica, 13th ser., Salt Range Fossils, I, Pt. 4, fas. 5, pp. 756–758. (Described and discussed as a new genus.)

Davidsonella WAAGEN, 1885, idem, pp. 762–764. (Described and discussed as a new genus.)

Not *Davidsonella* MUNIER-CHALMAR, 1880.

Lakhmina OEHLERT, 1887, Manuel de Conchyliologie, by Fischer, p. 1265. (Described in French.)

Lakhmina Oehlert, WAAGEN, 1891, Mem. Geol. Survey India, Paleontologia Indica, 13th ser., Salt Range Fossils, IV, Pt. 2; description of plate 11, figs. 3–4. (No text reference.)

Lakhmina Oehlert, HALL and CLARKE, 1892, Eleventh Ann. Rept. State Geologist New York for 1891, pp. 234–235. (Described.)
Neobolus Waagen, HALL and CLARKE, 1892, idem, p. 245. (Described.)
Lakhmina Oehlert, HALL and CLARKE, 1892, Nat. Hist. New York, Paleontology, VIII, Pt. I, pp. 28–30. (Described and discussed.)
Neobolus Waagen, HALL and CLARKE, 1892, idem, p. 84. (Described and discussed.)

General outline of shells broad oval to subcircular; nearly equivalve, moderately convex. Shell substance calcareo-corneous and probably phosphatic, structure laminated. Surface with concentric striation. Shell strong for its size and built up on its anterior and lateral margins of several thin layers or lamellæ. Apex of ventral valve small and slightly projecting over a low false area that appears to have an open delthyrium. Apex of dorsal valve marginal.

The interior of the ventral valve has a strong rounded central ridge extending from the narrow area about one-third the length of the shell, and a strong ridge on each side that extends from the same point of origin as the central ridge obliquely forward nearly to the frontal margin of the shell.[1] Between the central ridge and the posterior portions of the lateral ridges there are slightly concave shelves forming with the central ridge a triangular platform, with an open space beneath the concave shelves; numerous radiating striæ occur on the concave shelves and the inner surface of the shell.

Of the muscular impressions in the ventral valve, Dr. Waagen wrote [1885, p. 762] that "nothing can be observed." Considered from the point of view of the Trimerellidæ, this may appear to be correct; but if we compare the muscle scars of *Obolus* with what appear to me to be points of attachment of muscles, there is no difficulty in recognizing a few scars. Just beneath the outer extension of the narrow area of the ventral valve there is a minute, clearly defined elongate oval space that corresponds to the divided umbonal muscle scar in *Obolus apollinis* Eichwald [1829, p. 274]. Near the outer margin, on a line with the anterior portion of the central ridge, there is a narrow elongate space which, under a strong reflected light, is seen to be divided diagonally by a slight, narrow, raised line. Compared with *Obolus,* this space is the point of attachment of the transmedian and anterior lateral muscle scars. It is probable that the outside and middle lateral muscle scars and the centrals were attached to the platform, but there are no defined muscle scars upon it.

[1] I do not find any indication of the incurving of these ridges as described and illustrated by Dr. Waagen [1885, p. 762, pl. LXXXV, fig. 6].

The interior of the dorsal valve has several very unusual characters. There is no true cardinal area, unless the thick margin of the shell be considered as such. From the center of the cardinal margin a strong flat process, marked by concentric lines of growth, projects forward into the valve and rises a little above the plane of the margin of the valve. Dr. Waagen [1885, p. 763] calls attention to the resemblance between this process and the tooth of *Trimerella lindströmi*. From beneath the median process a short thick platform projects upward and forward into the valve; it is as wide as the process at its base, expanding toward its front margin. It is concave between its lateral crests, and the outer slopes are slightly concave from the crest to the body of the shell. In front the concave space and crests terminate rather abruptly above the front face, which in turn is underlain by a transversely hollow space of unknown extension beneath the platform. Toward each end of the frontal area a minute depression appears to indicate the point of attachment of a muscle. A narrow, rounded median septum extends from beneath the platform well toward the front of the shell. Two more or less interrupted and obscure ridges, indicating the main vascular trunks, extend from the front antero-lateral angles at the base of and at the side of the platform obliquely outward into the valve. The elongate smooth spaces outlined by Dr. Waagen [1885, pl. LXXXV, fig. 6] in his illustrations of this valve are too indefinite to be given form in the drawing of the only specimen showing the interior. What appears to be a small muscle scar occurs at the cardinal angle; it corresponds in position to the transmedian scar of *Obolus*.

TYPE.—*Neobolus warthi* Waagen.

OBSERVATIONS.—Through the courtesy of Dr. T. H. Holland, Director of the Geological Survey of India, I received the type specimens of *Neobolus, Davidsonella,* and *Lakhmina,* studied, described, and illustrated by Dr. Waagen. With these before me, I find that the elaborate figures of Waagen [1885, pl. LXXXV] are diagrammatic to a considerable extent; also that I cannot clearly recognize some of the characters noted by Dr. Waagen.

Dr. Waagen's original description [1885, p. 762] of the genus *"Davidsonella"* is very full and he also gives a detailed description of the type species *"D. linguloides."* Dr. Œhlert [1887, p. 1265] evidently based his description of *"Lakhmina"* on Waagen's description and illustrations, apparently not noting that Waagen stated in his text [1885, p. 762] that the elongate areas on the sides of the interior of the shell were not muscle scars, but that he considered them

as smooth areas outside the crescent. Dr. Œhlert [1887, p. 1265] says also that *Lakhmina* has "a straight and projecting beak perforated for the passage of the foramen," and reproduces Dr. Waagen's figures showing a deep pedicle furrow. Only one shell shows the apex of the ventral valve and the small false area beneath, and one other of the interior shows the true area and a triangular depressed spot at the center. A fracture at the center has broken out a bit of the shell, which gives rise to the narrow, deep furrow described by Waagen. The ventral valve has a false area beneath the apex; a true area on a plane with the margins of the valve.

When looking over the types of *Neobolus* and *Lakhmina* for the purpose of having illustrations made of them, I noted that there was a strong resemblance between the shells of the two genera; but, having the impression that the ventral valve of *Lakhmina* had a pedicle opening at the apex, drawings were arranged on the plates under the conception that *Lakhmina* belonged with the Neotremata. Dr. Charles Schuchert noted the same resemblance when looking over the plates of this monograph and called my attention to it. I then made a careful study of all of the specimens, and by the use of acid developed several interiors of dorsal valves. I found that the supposed perforation of the apex of the ventral valve of *Lakhmina* was the result of the breaking out of the minute apex; that the dorsal valve of *Neobolus warthi* was the same as the dorsal valve of *Lakhmina linguloides,* and that two genera and four species had been based on specimens of *Neobolus warthi.*

The external characters of all of the shells referred to *Neobolus* and *Lakhmina* are the same. Only one specimen of the interior of the ventral valve that shows anything of the platform beneath the visceral area occurs in the collections; this was referred to *Lakhmina* by Waagen, but the accompanying dorsal valves were first described as *Neobolus.* By comparing the illustrations of Waagen [1891, pl. II], the student will notice that figure 8*c* of the interior of the dorsal valve of *Neobolus* is essentially the same as the interior of the dorsal valve of *Lakhmina,* figure 4*c,* with the exception of the thickened platform.

It may seem as though it were forcing unlike forms into one species to place all these specimens together, but with our present information it appears to be necessary to do so.

All authors have classified the shells described as *Lakhmina* with *Trimerella linguloides,* and Hall and Clarke [1892*b*, p. 29] state that in the present condition of knowledge it must be regarded as the earliest representative of the Trimerelloid brachiopods. The ex-

ternal form is similar to that of *Obolus* and the interior characters might readily have been developed from that genus.

Genus DICELLOMUS Hall [1873, p. 246]

DICELLOMUS PARVUS, new species

PLATE 8, FIGURES 2 AND 2a

General form ovate, with the ventral valve subacuminate and dorsal valve broad oval to subcircular. Valves moderately convex. Surface of outer shell dark and polished; it is marked, when not abraded, by fine, clearly defined, concentric striæ and occasional lines of growth. The largest ventral valve has a length of 2.5 mm. and a width of 2 mm. The shell is strong but not thick. Shell substance apparently calcareo-corneous.

Ventral valve uniformly convex, except that the slopes toward the cardinal margins are more abrupt than elsewhere; apex appears to be marginal. The interior of the valve shows a short, low median ridge in the center of the visceral cavity; on each side and a little in front of the end of the median ridge are the trapezoidal areas for the attachment of muscle scars; rather small, composite cardinal muscle scars occur close to the cardinal margins.

Dorsal valve somewhat less convex than the ventral; apex marginal. The interior of the valve shows well-defined composite cardinal muscle scars, a narrow median septum, and a faintly impressed main vascular sinus that curves outward and forward at about one-third the distance from the outer margin to the median septum; the central muscle scars are small and situated back of the center of the valve on each side of a low median swelling on which the median septum occurs; the position of the anterior lateral muscle scars is indicated at the end of the median septum a little in advance of the center of the valve.

OBSERVATIONS.—This minute shell has the generic characters of *Dicellomus politus* (Hall) [1861, p. 24], but it differs specifically in its minute size and in the position of the muscle scars in the dorsal valve.

FORMATION AND LOCALITY.—Middle Cambrian: (1) *Ch'ang-hia limestone, 2.5 miles (4.02 km.) southwest of Yen-chuang, Sin-t'ai District, Shantung, China;* and (2) from a fine-grained bluish-black limestone river drift block one mile (1.61 km.) south of Ch'öng-ping-hien, on the Nan-kiang River, southern Shensi, China.

DICELLOMUS PROLIFICUS, new species

PLATE 8, FIGURES 3 AND 3*a*

This species differs from *Dicellomus politus* (Hall) [1861, p. 24], to which it appears to be most nearly related, by the greater convexity of the ventral valve, its higher umbo, and, in most shells, a greater narrowing toward the apex. The dorsal valve differs from that of *D. politus* in being more rounded on the cardinal margins. It is also to be noted that no traces of muscle scars or vascular markings have been observed on many interiors and casts of the interior of the valves, while in *D. politus* they are prominent on most casts and often on the interior of the valves. The range of outline of the valves of *D. politus* might include those of *D. prolificus,* but the convexity of the ventral valve and the smooth interior seem to distinguish the latter species.

Great numbers of the separated valves occur in several thin layers of gray limestone near the summit of the cliffs on the south side of Marjum Pass.

FORMATION AND LOCALITY.—Middle Cambrian: 2,900 feet (883.9 m.) above the top of the Lower Cambrian and 1,500 feet (457.2 m.) below the Upper Cambrian, in gray, thin-bedded limestone of the Marjum formation [Walcott, 1908*a*, p. 10], south side of Marjum Pass, in cliff southeast of the divide, House Range, Millard County, Utah.

Genus BOTSFORDIA Matthew [1891, p. 148]

BOTSFORDIA ? BARRANDEI, new species

Brachiopode, nouv. gen., DE VERNEUIL and BARRANDE, 1860, Bull. Soc. Geol. France, 2d ser., XVII, pp. 536–537, pl. VIII, figs. 5, 5*a–e*. (Described and discussed in French as a new genus.)

Acrothele POMPECKJ [not Linnarsson], 1896, Jahrb. kais.-könig. geol. Reichsanstalt, Bd. XLV, Heft 3, p. 603. (Discussed in German; see below for translation.)

Of this species Dr. Pompeckj [1896, p. 603] writes:

"From Barrande's description and figure, it is not quite easy to interpret this species. I have before me several specimens of a brachiopod from Coulouma, in the Department of Herault, which Miquel [1893, p. 4] mentioned as *'la Discina.'* I regard this form from southern France as belonging to the genus *Acrothele,* and believe that it is probably identical with the species mentioned by de Verneuil, Barrande, and Barrois as occurring in Spain."

With the specimens collected by M. Miquel before me, and which I have named *Acrothele bergeroni* (see p. 83), I do not think we

can consider them to be the same as the form described by de Verneuil and Barrande [1860, p. 536].

From M. Barrande's description and illustration, the following note is written: The shell is about as wide as long, suboval, with pointed beaks; valves moderately convex, with the ventral a little more so than the dorsal. There is a small area on each valve, but no trace of a triangular false deltidium. Beak of ventral valve with a minute pedicle opening. Surface with fine, distinct, concentric striæ. Substance of shell calcareous.

A shell 13 mm. in length has the same width, and the thickness of the two valves united is 5 mm.

M. Barrande thought that a new genus was indicated, but in the absence of interior characters decided not to name the genus or species. The perforate ventral valve and area suggested *Siphonotreta* to him, but the calcareous shell was opposed to it.

I have provisionally referred the shell to the genus *Botsfordia* and have named it after M. Barrande, whose memory all paleontologists take pleasure in recalling.

The reference to *Botsfordia* is made on account of (*a*) the subacuminate ventral valve with minute pedicle opening above a listrium unmarked by a false deltidium; (*b*) convex ventral and dorsal valve; (*c*) the tendency of *Botsfordia pulchra* (Matthew) [1889, p. 306] to have the substance of its rather thick shell replaced by calcareous matter.

I have attempted to secure specimens of this shell, but unsuccessfully. Until further information can be secured, the present reference will serve to indicate the probable relationship of the species.

FORMATION AND LOCALITY.—Middle Cambrian: Red limestone which passes north of Adrados and Boñar, near Sabero, Cantabrique Range, Province of Leon, Spain.

DEARBORNIA, new genus

This genus is based on one species, which is well represented by fourteen specimens. The generic description is incorporated with the description of the type species.

TYPE.—*Dearbornia clarki,* new species.

DEARBORNIA CLARKI, new species

PLATE 8, FIGURE 7

Shell subequivalve, subcircular in outline, slightly convex. Ventral valve most elevated at the pedicle aperture, which is circular, rather large, and situated from one-fifth to one-sixth the length of

the valve from the posterior margin; the slope back of the foramen is gently rounded and without a trace of false area or pedicle groove; the position of the beak is not clearly defined, as the margin is rounded and the uniform slope of the outer surface is unbroken. Dorsal valve uniformly and slightly convex; the position of the beak is indicated by a slight projection of the outline of the valve.

Surface marked by fine concentric lines. The substance of the shell is calcareous in an oölitic limestone in which semiphosphatic shells of *Obolus* are preserved. The shell is thick and apparently formed of one layer, but this is probably, as in the case of the shells of *Obolella crassa* (Hall) [1847, p. 290], a condition of preservation, the original layers or lamellæ having been replaced or else cemented together. The average size of the valves is from 3 to 5 mm.

The interior of the ventral valve does not show a true area; there is a space between the margin and the end of the median furrow into which the foramen opens. The median furrow is rather broad and deepest at the foramen; it extends forward beyond the center of the valve; the furrow into which the foramen opens is broadest at the posterior end and running out to a point a little in advance of the opening; from each side of the furrow and opposite the opening a furrow extends obliquely outward and then forward subparallel to the median furrow. Two large, oval muscle scars occur in the space between the outer furrow and the postero-lateral margin of the shell; these scars correspond in position to the transmedian and anterior lateral muscle scars of *Obolus* and *Trematobolus*. Nothing is clearly shown of the position of the main vascular canals unless the grooves outside of the median depression indicate their position, or it may be that they were on the narrow ridges outside of the side furrows and inside of the lateral muscle scars.

The interior of the dorsal valve shows a rudimentary area much like that of *Rustella edsoni* Walcott [1905*a*, p. 311]; the area is a smooth space with a slightly defined central depression, from which a narrow, low median septum extends forward to about the center of the valve; a narrow ridge extends forward from the posterior central depression on each side at about the inner third of the distance between the median septum and the outer margin; these ridges probably marked the position of the main vascular sinuses. The central muscle scars occur in the shallow depression on each side of the median septum a little back of the transverse center of the valve, and the transmedian scars and outside laterals are just outside of the narrow ridges on each side of the valve; these scars, like those in the ventral valve, are large for so small a shell.

OBSERVATIONS.—*Dearbornia clarki* is one of the simple or rudimentary forms of the Siphonotretidæ. It differs from *Siphonotreta* in the absence of an area and a siphonal or pedicle tube, in having the pedicle opening on the umbo in advance of the beak, and in its calcareous shell. The circular pedicle aperture without an exterior furrow, the absence of a well-defined area on the ventral valve, and its calcareous shell distinguish it from *Trematobolus* and *Schizambon*. The form and position of the pedicle opening suggest *Discinopsis*, but the interiors of the valves are very dissimilar in the two genera. It may be that with the discovery of good exteriors of the ventral valve of *Trematobolus excelsis* Walcott (see below) that species will be found to have a circular pedicle opening of the same character as that of *Dearbornia clarki*, but from the similarity of the cast of the interior of the ventral valve of the former species to that of *Trematobolus kempanum* (Matthew) [1897, p. 70] it is referred to *Trematobolus*.

The generic name is taken from Mount Dearborn, which was named after Gen. Henry Dearborn, and the specific name is given in recognition of Dr. William B. Clark's work on the paleontology of Maryland.

FORMATION AND LOCALITY.—Middle Cambrian: Lower portion of the Yogo limestone, in the canyon of the north fork of the Dearborn River, in the eastern part of the Lewis and Clark Forest Reserve, Montana.

Genus TREMATOBOLUS Matthew [1893, p. 276]

TREMATOBOLUS EXCELSIS, new species

PLATE 8, FIGURE 8

Shell transversely oval in outline, with both valves obtusely acuminate. Ventral valve strongly convex, with the minute beak at the posterior margin above a low area; the slope from the highest point of the valve, a little back of the center, is greatest toward the beak and nearly uniform to the front and sides of the valve. Pedicle opening unknown, as no exterior or cast of the exterior of the valve occurs in the material collected; two casts of the interior show the cast of the foramen at about the same position as in *Trematobolus insignis* Matthew [1893, p. 276] and other species of the genus. Dorsal valve slightly more transverse than the ventral and about two-thirds as convex; a very slight median flattening occurs at the anterior margin that extends back on the valve—nearly to the beak in some specimens; otherwise the convexity is distributed as in the ventral valve.

Surface marked by a few concentric lines of growth. The shell is rather thin except over the umbonal and posterior portions of the ventral valve, where it is moderately thick. Its substance is now calcareous and appears like that of *T. insignis;* the original shell may have been calcareo-corneous. A ventral valve 18 mm. in length has the same width; a large dorsal valve 22 mm. long has a width of 27 mm.

The area of the ventral valve is short and divided midway by a depressed subtriangular false pedicle furrow; the presence of pits on each side of the antero-lateral margins of the false pedicle furrow indicates that the area at these places projected in the same manner as that of *T. insignis* and *T. kempanum* (Matthew) [1897, p. 70]. The cast of the interior of the ventral valve shows a median ridge with the cast of the pedicle opening at about the posterior sixth of the length of the valve; only the imperfect outlines of the splanchnocœle are known; the main vascular sinuses are outlined for a short distance back of the transverse center sufficiently to indicate that their position was about the same as in *T. kempanum.* The position of the anterior lateral muscle scar is clearly shown just outside of the main vascular sinuses; it is elongate oval in outline and a little in advance of the transmedian scar; the umbonal muscle scars are close to the median furrow, as in *T. kempanum.* Interior of dorsal valve unknown.

OBSERVATIONS.—This fine species differs from all other known species of the genus in having the ventral valve more convex than the dorsal and in its greater size. It is the oldest species of the genus, occurring as it does well down in the section of the Lower Cambrian strata in association with *Olenellus.* There are a large number of specimens of the exterior of the dorsal valve, but only two interior casts of the ventral valve. The dorsal valves of *T. pristinus* (Matthew) [1895, p. 121] and *T. kempanum* also greatly outnumber the ventral valves in the collections. This circumstance may be owing to the presence of the foraminal furrow and interior median furrows; these would cause the shell of the ventral valve to break more readily than that of the dorsal.

FORMATION AND LOCALITY.—Lower Cambrian: (1) Shales and interbedded limestones at the south end of Deep Spring Valley; (2) shales at a higher horizon than (1), but at the same locality; (3) sandstone on ridge east of the head of Mazouka Canyon, Inyo Range; and (4) *arenaceous limestone one mile (1.61 km.) east of Saline Valley road, 2 to 3 miles (3.22 to 4.83 km.) east-northeast of Waucoba Springs;* all in Inyo County, California.

Genus ACROTHELE Linnarsson [1876, p. 20]

ACROTHELE ARTEMIS, new species

PLATE 8, FIGURE 10

General form of ventral valve moderately convex; subcircular and somewhat obtusely acuminate in outline; apex near the posterior margin; pedicle opening unknown, but from the occurrence of a small boss on the inside of the shell beneath the apex, it was probably of the same character as in closely related species.

Surface marked by concentric lines and small ridges of growth and an irregular system of fine granules on the concentric ridges; in the lower interspaces there is an irregular distribution of very minute inosculating ridges that, with the tubercles, forms a surface independent of the concentric growth lines. The shell is built up of numerous lamellæ beneath the outer surface layer and appears to have been corneous or composed of phosphate of lime and chitin. The largest shell has a length and width of 10 mm.; the apex is about 2 mm. from the posterior margin; dorsal valve unknown.

OBSERVATIONS.—This species resembles in form *Acrothele prima costata* (Matthew) [1895, p. 128], and both species have a granular surface. The latter species, however, has a thinner shell and its surface is marked by much larger granules. I do not know of any other closely related species.

FORMATION AND LOCALITY.—Middle Cambrian: Dark-blue limestones of the Langston formation just above the Cambrian quartzitic sandstone beds on the north side of Two Mile Canyon near its mouth, 2 miles (3.22 km.) southeast of Malad, Oneida County, Idaho.

ACROTHELE BELLAPUNCTATA, new species

PLATE 8, FIGURES 9 AND 9′

General form a broad transverse oval, with the posterior side slightly flattened and arched upward for a short distance below the apex. Ventral valve convex near the umbo and nearly flat over the anterior portion of the valve; apex near the posterior margin. Foraminal aperture apparently at the apex above a short, not distinctly marked false area. Ventral valve nearly flat and with the posterior margin curved downward so as to fill the space caused by the upward arching of the margin of the ventral valve. Surface of shell beautifully ornamented by elevated sharp oblique lines with deep interspaces that give a strongly punctate appearance to the

shell; concentric undulations and ridges of growth also occur in a more or less irregular manner. The inner layers or lamellæ are marked by fine, concentric, and rather strong radiating lines. The shell is built up of numerous thin layers or lamellæ of a corneous appearance.

A slightly compressed ventral valve has a length of 5 mm., with a width of 6.5 mm. A ventral valve 4 mm. in length has a width of 5 mm.

This is one of the most beautifully ornamented species of the genus. Its surface is not unlike that of some varieties of *Micromitra* (*Iphidella*) *pannula* (White) [1874, p. 6]. In form it suggests *Acrothele* (*Redlichella*) *granulata* (Linnarsson) [1876, p. 24]. Nothing is known of the interior character of the valves.

FORMATION AND LOCALITY.—Lower Cambrian: Shales in upper portion of *Olenellus kjerulfi* zone, Ringsaker, Province of Hedemarken, Norway.

ACROTHELE BERGERONI, new species

PLATE 8, FIGURE 11

La Discina MIQUEL, 1893, Note Sur la Géologie des Terrains Primaires du Département de l'Herault, St. Chinian à Coulouma, p. 9. (Mentioned in French.)

La Discina MIQUEL, 1894, Bull. Soc. d'Étude Sci. Nat. Beziers, for 1893, Mém. Compte Rendu des Séances, XVI, 1894, p. 106. (This article is a copy of the preceding reference, which was published as a separate.)

La Discina MIQUEL, 1894, Note Sur la Géologie des Terrains Primaires du Département de l'Herault, le Cambrien et l'Arenig, p. 10. (Mentioned in French.)

La Discina MIQUEL, 1895, Bull. Soc. d'Étude Sci. Nat. Beziers for 1894, Mém. Compte Rendu des Séances, XVII, 1895, p. 10. (This article is a copy of the preceding reference, which was published as a separate.)

All the specimens representing this species are flattened by compression in the argillaceous shale; also more or less distorted. A ventral valve 6 mm. in length has the apex 1.5 mm. from the posterior margin. A cast of the interior of a ventral valve indicates a relatively large interior opening for the pedicle tube; a short, small visceral cavity with the shell thickened so as to form a short ridge. and an obscure false area; also that the posterior margin is arched slightly above the plane of the margin of the valve. An exterior cast shows the impression of a minute elongate tubercle on each side of the apex and a small pedicle opening just back of them. A cast of the interior of a dorsal valve shows a short median ridge and the posterior portion of the main vascular sinuses.

The exterior cast shows that the surface was marked by small concentric ridges and lines of growth with a few low, obscure, rounded radiating ridges and fine granulations or tubercles on the very minute, irregular, more or less inosculating concentric ridges, or the same type of surface as that of *Acrothele coriacea* Linnarsson [1876, p. 21]. If these shells were found at the same horizon in Sweden as *A. coriacea,* I think they would be referred to that species, except that the apex of the ventral valve of the French species is much nearer the posterior margin; more perfect specimens would probably show other differences.

This species appears to differ from *Acrothele quadrilineata* Pompeckj [1896, p. 511] and *A. bohemica* (Barrande) [1879, pl. 102, figs. VII: 1-3] by the more anterior position of the apex of the ventral valve.

In response to a request for permission to study the Cambrian brachiopods that he had collected from Montagne Noire, M. Miquel very courteously sent me a number, and among them I found this species, and, with his permission, have described it.

It gives me pleasure to give the specific name in recognition of the discovery by Prof. J. Bergeron of the Middle Cambrian fauna of Herault, and of his fine work on the fauna.

FORMATION AND LOCALITY.—Middle Cambrian: Shales, in Montagne Noire, Coulouma, Department of Herault, France.

ACROTHELE BORGHOLMENSIS, new species

PLATE 8, FIGURE 12

General form subcircular to broad oval. Ventral valve subconical, with the apex a short distance back of the center. A clearly defined false area extends from the apex to the margin; it is defined by a slight depression and a low ridge at the outer edges; two or three longitudinal lines extend to the margin and the concentric lines of growth of the shell cross it without interruption. An elongate, small foraminal aperture occurs just back of and beneath the apex.

The outer surface of the shell is of a dull, dark color and marked by slightly undulating, clearly defined, concentric striæ; the inner layers are marked by fine radiating and concentric lines. The shell is built up of thin lamellæ arranged in concentric layers that are slightly oblique to the surface layer. Shell substance corneous. Nothing is known of the interior of the valves except the sharp median ridge of the dorsal valve.

The largest specimen has a diameter of 4 mm.; the average size is about 3 mm.

OBSERVATIONS.—The material representing this species was collected by M. Schmalensee in the shaly beds of the Ceratopyge zone of Oeland. The convexity, position of the apex, and clearness of the false area depend upon the degree of compression and distortion to which the shells have been subjected. I have described what appears to be the uninjured shell.

The subcentral position of the apex seems to distinguish this species. It is associated with *Obolus* (*Bröggeria*) *salteri* (Holl) [1865, p. 102] and *Lingulella lepis* Salter [1866*b*, p. 334].

FORMATION AND LOCALITY.—Upper Cambrian: Ceratopyge slate at Borgholm, Oeland Island, Sweden.

ACROTHELE LEVISENSIS, new species

PLATE 8, FIGURE 13

Outline transversely broad ovate, ventral valve moderately convex at the apex, which is at about the posterior fifth of the length of the valve; pedicle aperture small and situated on the slope back of and near the apex. Dorsal valve depressed convex, with a very gentle slope from the umbo to the front margin and a greater slope to the marginal beak.

Surface marked by fine concentric lines and striæ that cross the space back of the apex without apparent interruption. A compressed ventral valve 8 mm. in length has a width of 10 mm. A dorsal valve has a length of 7 mm.; width, 8 mm.

The cast of the interior of a compressed dorsal valve shows a median ridge that expands near the center of the valve, and a main vascular sinus on each side that has the same general course as in *Acrothele coriacea* Linnarsson [1876, p. 21].

OBSERVATIONS.—In general form this species is much like *Acrothele coriacea* and related species. It differs from them in having a smooth surface except for the concentric lines and striæ.

The four specimens representing this species were attached to a block in the collections of the Geological Survey of Canada, with specimens of *Elkania desiderata* (Billings) [1862, p. 69].

FORMATION AND LOCALITY.—Lower Ordovician: Levis shales, Point Levis, Province of Quebec, Canada.

ACROTHELE SPURRI, new species

PLATE 8, FIGURE 14

Acrothele subsidua WALCOTT (in part) [not White], 1886, Bull. U. S. Geol. Survey, No. 30, p. 109, pl. IX, fig. 4 (not figs. 4*a–c*). (Locality mentioned in discussion of *A. subsidua*. The specimen represented by fig. 4 is redrawn in this paper, pl. 8, fig. 14.)

Acrothele subsidua WALCOTT (in part) [not White], 1891, Tenth Ann. Rept. U. S. Geol. Survey, p. 608, pl. LXX, fig. 1 (not figs. 1*a–c*). (Mentioned. Fig. 1 is copied from fig. 4 of preceding reference.)

General form transversely ovate. Ventral valve depressed, with an elevated apex a little in front of the posterior margin; from the apex the surface slopes rapidly and then gradually to the front margin and quite rapidly to the posterior margin; the posterior margin arches up from the plane of the sides of the valves about one-half the height of the apex and gives to the valve the appearance of being pushed up so as to throw the apex toward the front; a minute pedicle opening truncates the apex at its posterior side; a small, subtriangular, convex false area extends from just back of the apex to the posterior margin.

Surface of the epidermal layer marked by fine, concentric striæ of growth and a very minute granulation; the inner laminations of the shell are shiny and marked by numerous radiating striæ and a few concentric lines. Shell corneous and built up of numerous layers or lamellæ more or less oblique to the outer layer.

Dorsal valve and interior of valves unknown. The largest ventral valve has a length of 6 mm.; width, 7 mm.

OBSERVATIONS.—This very striking species is associated with *Acrotreta primæva* Walcott [1902, p. 593] and *Olenellus gilberti* Meek in the upper portion of the Olenellus zone of central Nevada. Some fragmentary specimens of this species were referred by me [1886, p. 109] to *Acrothele subsidua* White [1874, p. 6], but with better material and more thorough study the Lower Cambrian specimens are referred to *A. spurri*. *A spurri* differs from *A subsidua* in the more posterior position of its apex; in its convex, distinctly marked false area; in its strongly arched posterior margin, and in its more finely granulated surface. The convex false area and arched posterior margin are features also seen in *A. woodworthi* (see p. 88) of the Lower Cambrian.

FORMATION AND LOCALITY.—Lower Cambrian: *Associated with Olenellus in the shales and thin interbedded layers of limestone of the Pioche formation* [Walcott, 1908*a*, p. 11], *just above the quartzite on the east side of the anticline near Pioche, Lincoln County, Nevada.*

Doubtfully: Lower Cambrian sandy shales 2.5 miles (4.02 km.) south of Barrel Spring and .5 mile (.80 km.) east of the road, Silver Peak quadrangle (U. S. G. S.), Esmeralda County, Nevada.

ACROTHELE SUBSIDUA HERA, new variety

PLATE 8, FIGURE 15

This variety is separated from *Acrothele subsidua* White [1874, p. 6] by the more elongate outline of the ventral valve, and more posterior position of the apex, the relative position of the latter being between the posterior position of the apex of *Acrothele spurri* (see p. 86) and the more anterior position of the apex of *A. subsidua*. An obscurely defined false area begins at the apical opening and diverges toward the margin. It is marked by a slight median ridge. The exterior layers of the shell are exfoliated, carrying with them the outer portion of the apical opening. The inner portion is rather large, and from the presence of an elongate tubercle on each side it is apparent that there was a similar tubercle on the exterior surface on each side of the apex a little in advance of the opening.

The surface of an interior layer is marked by fine concentric lines, numerous very fine radiating lines, and four sharp ridges that radiate from the apex to the front margin.

OBSERVATIONS.—This species is represented by a single specimen that occurs in the buff-weathering, gray limestone interbedded in a shale carrying fragments of *Olenellus*. It is quite distinct from *A. spurri*, with which it is associated, and appears to be a progenitor of *A. subsidua*, which occurs so abundantly in the Middle Cambrian strata much higher up in the section.

FORMATION AND LOCALITY.—Lower Cambrian: Associated with *Olenellus* in the shales and thin interbedded layers of limestone of the Pioche formation [Walcott, 1908*a*, p. 11], just above the quartzite on east side of anticline, near Pioche, Lincoln County, Nevada.

ACROTHELE TURNERI, new species

PLATE 9, FIGURE 12

General outline broad oval, ventral valve slightly conical, with the apex at about the posterior third of the length of the valve; apex short and perforated on the back side of its point by a minute pedicle opening; false area indicated by a slight flattening between the apex and posterior margin. Dorsal valve gently convex; beak marginal.

Surface marked by fine concentric lines and striæ of growth. Shell corneous and made up of a few very thin lamellæ.

The largest shell has a length of 2.5 mm.; width, 2.75 mm.

OBSERVATIONS.—This neat little shell differs from *Acrothele subsidua* (White) [1874, p. 6] in the absence of the surface characters of that species and from *A. spurri* (see p. 86) by the more anterior position of its beak and smooth surface. It belongs to the group of *Acrothele* represented by *A. borgholmensis* (see p. 84).

FORMATION AND LOCALITY.—Middle Cambrian: *Calcareous shales 10 miles (16.09 km.) south-southeast of Emigrant Peak, Silver Peak quadrangle (U. S. G. S.), Esmeralda County, Nevada.*

Doubtfully: Middle Cambrian shaly limestones about 750 feet (228.6 m.) above the top of the Cambrian quartzitic sandstones and 3,440 feet (1,048.5 m.) below the Upper Cambrian, about 9 miles (14.48 km.) above the mouth of Blacksmith Fork and 16 miles (25.75 km.) east of Hyrum, Cache County, Utah.

ACROTHELE WOODWORTHI, new species

PLATE 9, FIGURE 11

Ventral valve transversely and irregularly oval in outline, convex, with the apex a little back of the center of the valve; pedicle opening, as indicated by the matrix of the exterior, just back of the apex; a subtriangular, gently convex false area is obscurely outlined by lines radiating from the apex to the posterior margin; the posterior margin is arched upward one-third or more of the distance from the plane of the margin of the valve to the apex.

Surface marked by concentric growth lines with fine striæ between, and a number of low, rounded, more or less obscure, radiating ribs. The shell is relatively thick and replaced by the calcareous matter of the matrix.

OBSERVATIONS.—This species is based on two specimens of the ventral valve collected by Prof. J. B. Woodworth. The generic reference is not entirely satisfactory, as the pedicle opening has not been clearly seen and the convex false area suggests the area of *Micromitra* more than that of any *Acrothele* except *A. spurri* (see p. 86).

FORMATION AND LOCALITY.—Lower Cambrian: Nahant limestone, Pulpit Rock, Nahant, Essex County, Massachusetts.

ACROTHELE YORKENSIS, new species

PLATE 9, FIGURE 10

This species is represented in the fine clay shales by casts of the exteriors of the valves and a few imperfect casts of the interior. The shell is large for a species of this genus. Ventral valve mod-

erately convex, with the apex, in a specimen 9 mm. long, 1.5 mm. from the posterior margin. The general outline is subcircular, with the length and width approximately the same. Dorsal valve with the apex marginal. The original convexity of the valves is unknown, as all of the specimens are flattened in the shale.

Surface marked by concentric ridges and striæ of growth and a few obscure, rounded, radiating ridges. In addition, there is a fine granulation of the type of that of *A. coriacea* Linnarsson [1876, p. 21], the irregular, more or less inosculating, minute, rounded ridges having fine tubercles upon them.

A large ventral valve has a length and width of 11 mm. Other specimens of the same size occur, although the average size is about 8 mm. Substance of the shell is unknown.

One or two poor interiors of the ventral valve show a small visceral cavity and rather slender main vascular sinuses that appear to originate beside the pedicle opening. The latter opens on the back slope of the apex and enlarges as it passes through the shell. The interior of the dorsal valve shows a rather strong central ridge that extends beyond the center of the shell; also a rather small cardinal scar on each side of the median ridge close to the posterior margin.

OBSERVATIONS.—This shell is of the general type of *Acrothele matthewi* (Hartt) [1868, p. 644]. It differs in its larger size, and it is not probable that a species would occur in the inner Appalachian trough which is present in the sediments near the margin of the Atlantic basin. The fauna associated with *A. yorkensis* is of the Middle Cambrian type of the interior trough and quite unlike that of the *Paradoxides* fauna of the Atlantic Coast Province. In size this species approaches *A.* (*Redlichella*) *granulata* (Linnarsson) [1876, p. 24], but it differs from that species in its minutely granulated surface.

FORMATION AND LOCALITY.—Middle Cambrian: Argillaceous shales in railroad cut alongside of gas-house, city of York, York County, Pennsylvania.

REDLICHELLA, new subgenus of ACROTHELE

This subgenus of *Acrothele* has all the external characters of the type species of *Acrothele, A. coriacea* Linnarsson [1876, p. 21]. It differs in the interior markings of the valves. The visceral area of the ventral valve is large and clearly defined, as in *Botsfordia granulata* (Redlich) [1899, p. 5], and the main vascular sinuses are very strong and close to the pedicle aperture, as in the latter species. In

the interior of the dorsal valve the cardinal scars are very large and extend forward nearly one-third the length of the valve.

TYPE.—*Acrothele granulata* Linnarsson [1876, p. 24].

I was at first inclined to place this form under *Botsfordia,* but the advanced position of the apex and pedicle opening of the ventral valve indicates a closer affiliation with *Acrothele.* The short listrium of *Botsfordia* has developed in *Redlichella* to the strong false area of *Acrothele,* but the visceral area and main vascular sinuses of *Botsfordia* remain practically unchanged. I regard *Redlichella* as a form intermediate in development between *Botsfordia* and *Acrothele.*

Genus LINNARSSONELLA Walcott [1902, p. 601]

LINNARSSONELLA MODESTA, new species

PLATE 9, FIGURES 8 AND 8*a*

Shell minute; general form subcircular. Ventral valve moderately convex; beak small and slightly incurved over a very low false area; foraminal opening minute exteriorly, with a slightly elevated, sharp ridge on each side a little in advance of the point of the beak; seen from the back, the minute aperture points backward from the bottom of a pit between the two short, sharp ridges. In a specimen from a layer of limestone a short distance above in the section the aperture is at the point of a small nipple-like projection, apparently formed by the union of the ends of the ridges, already described, on each side of the aperture. Dorsal valve slightly convex, with a minute beak at the posterior margin.

Surface dull when the outer layer of the shell is preserved; it is marked by a few very fine, concentric lines of growth. The inner surface is marked by concentric lines and a few fine, radiating lines. The shell is formed of several layers or lamellæ and is relatively thin.

The average diameter of the adult shell is from 1.75 to 2.25 mm.; the dorsal valve is slightly shorter than the ventral.

The cast of the interior of the ventral valve shows a slight longitudinal median elevation and two short, not very strongly marked main vascular sinuses; several specimens indicate a slight cavity just beneath the aperture which probably represents the inner side of the foraminal tube. The interior of a dorsal valve shows main vascular sinuses quite close to the outer margin; also two small, rounded median depressions a short distance in front of the posterior margin.

OBSERVATIONS.—This shell occurs in great abundance on the surface of shaly gray limestone about midway of the strata referred to

the Upper Cambrian in the House Range Section. It differs from *L. nitens* (see below), which occurs a short distance above it in the section, and with which it is also associated, in having a less elevated ventral valve and a less convex dorsal valve, and from *L. transversa* (see p. 92) in being more rounded in outline and less convex. It appears to be more nearly related in form to *L. minuta* (Hall and Whitfield) [1877, p. 206]; it differs, however, materially in the character of the interior markings of the ventral valve, features which also separate it from *L. girtyi* Walcott [1902, p. 602] and *L. tennesseensis* Walcott [1902, p. 604].

FORMATION AND LOCALITY.—Upper Cambrian: 1,160 feet (353.6 m.) above the Middle Cambrian and 2,155 feet (656.8 m.) below the top of the Upper Cambrian, in the arenaceous shales and limestones of the Orr formation [Walcott, 1908*a*, p. 10], 4 miles (6.44 km.) south of Marjum Pass, House Range, Millard County, Utah.

LINNARSSONELLA NITENS, new species

PLATE 9, FIGURE 7

The outline of the valves and the exterior appearance of this shell are much like those of *Linnarssonella modesta* (see p. 90). It differs in having on the ventral valve a low, distinct area, with the perforated apex directed backward on nearly the same plane as the umbo, or most elevated portion of the valve. The dorsal valve is more convex and its interior has a strong median ridge extending forward from the posterior margin about two-thirds of the distance to the front margin, a feature but little developed in *L. modesta*. From *L. minuta* (Hall and Whitfield) [1877, p. 206] it differs in the higher apex of the ventral valve, and from *L. transversa* (see p. 92) in the latter character and in the more circular outline of the aperture of the valves.

A single specimen of *L. modesta* was found associated with this species.

In size *L. nitens* varies from 1.5 to 2 mm. in diameter.

FORMATION AND LOCALITY.—Upper Cambrian: (1) *1,160 feet (353.6 m.) above the Middle Cambrian and 2,155 feet (656.8 m.) below the top of the Upper Cambrian, in the arenaceous shales and limestones of the Orr formation* [Walcott, 1908*a*, p. 10], *4 miles (6.44 km.) south of Marjum Pass, House Range, Millard County, Utah.* (2) About 2,575 feet (784.9 m.) above the top of the Cambrian quartzitic sandstones, in a blue limestone about 2 miles (3.22 km.) southeast of Muskrat Spring, on the northwest face of Grantsville Peak, Stansbury Range, Tooele County, Utah.

LINNARSSONELLA TRANSVERSA, new species

PLATE 9, FIGURE 6

This is a small shell that at first sight suggests *L. modesta;* it differs from that species in the valves being more convex, transverse instead of circular, and in having stronger concentric striæ, and, in some instances, radiating striæ. A few fragments of the interior of the dorsal valve indicate that the main vascular sinuses are well out toward the outer margin, and that small circular depressions occur on each side of the median line, very much as in the dorsal valve of *L. girtyi* (Walcott) [1902, p. 602], and two small central muscle scars midway between the posterior and anterior margins of the valve. *L. transversa* differs from all other species of the genus known by its transverse outline. The average shell has a width of 2 mm., with a length of from 1.5 to 1.75 mm.

FORMATION AND LOCALITY.—Upper Cambrian: At 930 feet (283.5 m.) above the Middle Cambrian and 2,385 feet (726.9 m.) below the top of the Upper Cambrian, in the arenaceous shales and limestones of the Orr formation [Walcott, 1908*a*, p. 10], 4 miles (6.44 km.) south of Marjum Pass, House Range, Millard County, Utah.

LINNARSSONELLA URANIA, new species

PLATE 9, FIGURES 9 AND 9*a*

Shell minute, general form elongate oval. Ventral valve convex; apex minute and curved down nearly to the plane of the margin of the valve; false area, if present, must be very narrow. Foraminal opening situated on the umbo a short distance above the point of the beak; on some shells it opens on the plane of the valve, and on others it has a rounded, slightly elevated margin. Dorsal valve slightly convex, with a minute beak at the posterior margin. Surface of the shell glossy, with very fine concentric striæ and lines of growth. A ventral valve 2.5 mm. in length has a width of 1.75 mm. The dorsal valves are somewhat shorter in proportion to the width.

A partial cast of the interior of the ventral valve shows a small visceral area in front of the foraminal opening. The interior of the dorsal valve is marked by a strong central ridge that extends from the beak four-fifths of the distance to the front margin; on each side of the median ridge, near the posterior margin, there is a rather large, clearly defined cardinal muscle scar.

OBSERVATIONS.—This shell occurs in considerable numbers in a compact, hard, dove-colored limestone 60 to 75 feet (18.3 to 22.9 m.)

above the sandy shales of the Big Cottonwood Canyon Section, Utah. The associated fragments of trilobites indicate the Middle Cambrian fauna of the Wasatch Range Section.

This species differs from *L. girtyi* (Walcott) [1902, p. 602] in not having a false area in the ventral valve and also in the position of the foraminal opening. The incurved apex is more like *L. modesta* (see p. 90), but the form of the ventral valve and the position of the foraminal aperture are quite different.

FORMATION AND LOCALITY.—Middle Cambrian: Limestones about 200 feet (61 m.) above the Cambrian quartzitic beds, about .25 mile (.40 km.) below the Maxfield Mine, Big Cottonwood Canyon, west front of the Wasatch Mountains, southeast of Salt Lake City, Utah.

Genus ACROTRETA Kutorga [1848, p. 275]

ACROTRETA BELLATULA, new species

PLATE 9, FIGURES 4, 4*a–b*

General outline subcircular to transversely broad oval, with the posterior margin of the ventral valve nearly straight beneath the false area. The ventral valve is moderately convex, with the apex a little in front of the posterior margin. False area defined by the incurving of the cardinal slopes so as to form a somewhat flattened triangular space that is divided midway by a narrow and rather shallow vertical furrow; pedicle aperture of medium size and opening slightly backward. Dorsal valve nearly as convex as the ventral, except that it curves down in the posterior portion to a minute marginal beak.

Surface of the shell marked by fine, concentric striæ and lines of growth that show marked variations in their sharpness on different specimens, the older shells having a dark, dull surface giving the effect of a thin film over the striæ; a few traces of radiating striæ are shown on some shells.

The average length of the larger shells is about 1.75 mm.; width, 2 mm.

The interior of the ventral valve shows a small apical callosity, minute pedicle tube, and vascular sinuses originating a little back of the apical callosity; a cast shows that there were medium-sized, elevated cardinal muscle scars. An interior cast of the dorsal valve indicates a median ridge that extended about four-fifths of the distance from the area to the front margin. It also indicates medium sized, elevated cardinal muscle scars. A second specimen shows a shorter median ridge, with small, elevated central muscle scars about half way between the posterior and front margins of the shell.

OBSERVATIONS.—This species belongs to the *Acrotreta sagittalis* (Salter) [1866*a*, p. 285] group. The low convexity of the ventral valve, posterior position of the apex, the strong cardinal muscle scars, and the strong median ridge, cardinal and central muscle scars of the dorsal valve are all features common to *Acrotreta bellatula* and *A. sagittalis*. It differs from *A. sagittalis* in the more posterior position of the apex and less convexity of the ventral valve, and from *A. definita* Walcott [1902, p. 584] in its much smaller size and less elevated ventral valve.

FORMATION AND LOCALITY.—Middle Cambrian: 2,825 to 3,025 feet (861.1 to 922 m.) above the top of the Lower Cambrian and 1,400 to 1,600 feet (426.7 to 487.7 m.) below the Upper Cambrian, in the gray thin-bedded limestone of the Marjum formation [Walcott, 1908*a*, p. 10], south side of Marjum Pass, in cliff southeast of the divide, House Range, Millard County, Utah.

ACROTRETA MARJUMENSIS, new species

PLATE 9, FIGURES 2 AND 2*a*

The general form of this species is much like that of *Acrotreta idahoensis* Walcott [1902, p. 587]. The ventral valve differs in having a more strongly marked and broader false area and in the greater curvature of the apex over the false area. It is also less elevated, or convex, in proportion to the size of the shell. It may also be compared with *A. neboensis* Walcott [1905*a*, p. 300], from which it differs in being less elevated and in not having a well-indicated false pedicle furrow. The dorsal valve is moderately convex and differs little from the dorsal valve of *A. idahoensis* and *A. neboensis*.

The interior of the dorsal valve shows a narrow median ridge that, at the center and toward the front of the shell, rises as a sharp, rather high, and very narrow ridge. This ridge starts posteriorly from a subtriangular, somewhat elevated area which has a longitudinal furrow crossing it. The cardinal and central muscle scars are very clearly defined; in some cases the central scars are slightly depressed, and in other shells elevated above the general surface of the interior of the shell.

FORMATION AND LOCALITY.—Upper Cambrian: Thin-bedded blue limestone at the base of the high point southwest of the J. J. Thomas ranch, on the east side of the Fish Spring Range, Juab County, Utah.

Middle Cambrian: *About 3,025 feet (922 m.) above the top of the Lower Cambrian and 1,400 feet (426.7 m.) below the Upper Cambrian, in the gray, more or less thin-bedded limestone of Marjum*

formation [Walcott, 1908a, p. 10], south side of Marjum Pass, in cliff southeast of divide, House Range, Millard County, Utah.

ACROTRETA OPHIRENSIS DESCENDENS, new variety

PLATE 9, FIGURES 1 AND 1a

In the Cambrian Section of the House Range, Utah, the typical forms of *Acrotreta ophirensis* Walcott [1902, p. 591] occur in the Marjum formation; 1,550 feet (472.4 m.) higher in the section, in the Weeks formation, there are great numbers of a shell identical in many respects. This latter shell differs from the typical form in being less convex in both the ventral and dorsal valves and in having a more pointed, less curved apex on the ventral valve.

FORMATION AND LOCALITY.—Middle Cambrian: About 3,750 feet (1,143 m.) above the top of the Lower Cambrian and 650 feet (198.1 m.) below the Upper Cambrian, in shaly limestones of the Weeks formation [Walcott, 1908a, p. 10], north side of Weeks Canyon, 3.5 miles (5.63 km.) south of Marjum Pass, House Range, Millard County, Utah.

ACROTRETA RUDIS, new species

PLATE 9, FIGURE 5

Acrotreta kutorgai WALCOTT (in part), 1902, Proc. U. S. National Museum, XXV, pp. 589–590. (Described as a new species, but the description included specimens belonging to both *A. kutorgai* and *A. rudis*.)

The specimens illustrating this species are all more or less crushed and flattened on the surface of the fine argillaceous shale in which they are embedded in large numbers, and they are often in the condition of casts of the interior of the valves.

The ventral valve, as far as can now be determined, was elevated, conical, and with the apex overhanging the false area, so that when the shells were crushed down the posterior side disappeared beneath. A few fragmentary specimens show the false area to have been distinctly defined, of medium height, and marked by a narrow, shallow median furrow extending from the apex to the margin of the valve. Dorsal valve subcircular, slightly transverse, gently convex, and with a minute beak at the posterior margin. The pedicle opening appears to have been of medium size and situated at the apex of the valve.

Surface marked by lines of growth and very fine concentric striæ that continue across the false area and furrow.

The cast of the interior of the ventral valve shows a small but well defined visceral area in advance of the apex and a short, strong,

main vascular sinus on each side of the area; one cast shows traces of the sinuses nearly to the front margin. The interior of the dorsal valve is marked by a strong median septum or ridge that extends from the front of a small cardinal area forward to nearly the anterior margin in some examples. A large, oval cardinal muscle scar occurs on each side of the median ridge near the posterior border of the valve; the central muscle scars are small, elongate oval, and situated on the sides of the median ridge at about the posterior third of the longitudinal axis of the shell; the two antero-lateral muscle scars are on the sides of the median ridge a little in advance of the central scars.

This is one of the large species of the genus. A dorsal valve 4 mm. in length has a width of 4.5 mm. The ventral valves average from 4 to 4.5 mm. from the apex to the front margin.

In size and outline this species may be compared with *Acrotreta depressa* (Walcott) [1889, p. 441] and *A. definita* Walcott [1902, p. 594]. It differs from both in its ventral valve being more elongate. All the specimens of *A. rudis* are so flattened in the shale that comparison with uncompressed specimens is very difficult.

FORMATION AND LOCALITY.—Middle Cambrian: (1) *Rogersville shale, just above the road, in the hill west of the school-house, 3.5 miles (5.63 km.) from Rogersville, on the road to Melindy's Ferry;* and (2) Rogersville shale, road just east of Harlan's Knob, 4 miles (6.44 km.) northeast of Rogersville; both in Hawkins County, Tennessee.

ACROTRETA ULRICHI, new species

PLATE 9, FIGURE 3

This species is founded on a single specimen of a finely preserved ventral valve. The outline of the aperture is nearly circular, except for a short transverse portion beneath the false area; surface moderately convex, with the apex curving and ending beyond the posterior margin, so that the minute foraminal aperture opens backward; a small false area is indicated by a slight incurving at the cardinal angles; the area is without traces of a median furrow.

Surface of shell marked by very fine, concentric striæ and lines of growth. Length and width of aperture, 2 mm.; convexity of ventral valve, 1 mm.

OBSERVATIONS.—This species is characterized by its curved umbo and apex and overhanging false area. It most nearly resembles *A. curvata* Walcott [1902, p. 584], from which it differs in being less convex and in the form of its umbo and curved apex.

FORMATION AND LOCALITY.—Middle Cambrian: Reagan formation, limestone at northwest extremity of the Arbuckle Mountains, about 4 miles (6.44 km.) east of Homer, Woods County, Oklahoma.

Genus NISUSIA Walcott [1905*a*, p. 247]

NISUSIA RARA, new species

PLATE 9, FIGURES 13 AND 13*a*

The ventral valve of this species has the general form of that of *Nisusia festinata* (Billings) [1861*b*, p. 10], except that it has a very strong and deep median sinus and is more transverse; the delthyrium is also larger. *N. rara* occurs at the same stratigraphic horizon as *Nisusia alberta* (Walcott) [1889, p. 442], but it differs from the latter in having a larger delthyrium and a strong and deep median sinus.

The surface of *N. rara* is marked by rounded radiating ribs that increase by interpolation and bifurcation; small nodes on some of the ribs indicate the presence of spines on the outer surface. A portion of a convex deltidium is shown that has the outer portion broken away. The specimen represented by figure 13 has a length of 8 mm.; width, 16 mm.

FORMATION AND LOCALITY.—Middle Cambrian: Spence shale of the Ute formation, about 50 feet (15.2 m.) above the Cambrian quartzitic sandstones and 2,750 feet (838.2 m.) below the Upper Cambrian, in Spence Gulch, a ravine running up into Danish Flat from Mill Canyon, about 6 miles (9.65 km.) west-southwest of Liberty and 15 miles (24.14 km.) west of Montpelier, Bear Lake County, Idaho.

Subgenus JAMESELLA Walcott [1905*a*, p. 252]

NISUSIA ? (JAMESELLA ?) KANABENSIS, new species

This species is represented by a single broken interior cast of a small ventral valve that has a length of 3.5 mm.; width, about 5 mm. The cast is convex, with the base of a prominent extension that filled the interior of the beak. The surface is finely papillose, indicating that the interior surface was finely punctate. The casts of the ribs show them to have been rather sharply rounded and to have increased by bifurcation and interpolation; the absence of all traces of casts of spine bases on the ribs leads me to refer the species to the subgenus *Jamesella*. Area shown only by a narrow rim on one side. The delthyrium was probably quite broad.

The reference of this shell to *Nisusia* is based on the evidence of the presence of a prolonged beak and the character of the ribs. The genus is doubtful, but I do not know of any other to which a tentative reference could be made.

FORMATION AND LOCALITY.—Upper Cambrian: Thin-bedded limestones just below the base of the Ordovician; Lower Kanab Canyon, where it enters the Grand Canyon of the Colorado, Northern Arizona.

NISUSIA (JAMESELLA) LOWI, new species

PLATE 9, FIGURE 14

In form, outline, convexity, and cardinal area of the ventral valve this species resembles *Nisusia festinata* (Billings) [1861*b*, p. 10]. The surface of *N.* (*Jamesella*) *lowi* differs from that of *N. festinata* in having more and finer radiating ribs, clearly defined, rounded concentric striæ and lines of growth, and the absence of all traces of the surface spines, so characteristic of *N. festinata*. The latter is also a larger species. *N.* (*J.*) *lowi* averages 10 to 12 mm. across the hinge line and rarely over 8 mm. in the length of the ventral valve of the large shells of the species.

The specific name is in honor of Hon. A. P. Low, Deputy Head and Director of the Geological Survey of Canada.

Nisusia (*Jamesella*) *lowi* occurs at horizons 186 to 294 feet (56.7 to 89.6 m.) above the horizon of *Nisusia festinata* in the Mount Stephen Section.

FORMATION AND LOCALITY.—Lower Cambrian: (1) *About 5 feet (1.5 m.) below the top of the Lower Cambrian, in thin-bedded limestones of Mount Whyte formation;* (2) drift block of limestone supposed to have come from the horizon of (1); and (3) about 50 feet (15.2 m.) below the top of the Lower Cambrian, in shales of Mount Whyte formation; all three from north shoulder of Mount Stephen, just above the tunnel, on the Canadian Pacific Railway, 3 miles (4.83 km.) east of Field, British Columbia. (4) About 160 feet (48.8 m.) below the top of the Lower Cambrian, in oölitic limestones of Mount Whyte formation, slopes of Mount Bosworth, a little north of the Canadian Pacific Railway track, between Stephen and Hector, British Columbia.

WIMANELLA, new genus

This genus is proposed for the smooth, non-plicate species that I have heretofore referred to the genus *Billingsella*. *Wimanella* represents the smooth, early stages of development and *Billingsella* the

later, mature plicate stage of development of this section of the *Billingsellidæ*.

TYPE.—*Wimanella simplex*, new species.

It is to be noted that *Billingsella plicatella* Walcott [1905*a*, p. 240] includes some shells that are nearly smooth, and that *B. highlandensis* (Walcott) [1886, p. 119] is very finely costate. The former species may be considered as being in part a form intermediate between *Billingsella coloradoensis* (Shumard) [1860, p. 627] and *Wimanella harlanensis* (Walcott) [1905*a*, p. 236]. I think, however, that the species with smooth shells should be grouped under a generic head, as they indicate a marked phase in the evolution of the forms formerly grouped under *Billingsella*.

The generic name is given in recognition of the valuable work of Dr. Carl Wiman, of the University of Upsala, on the geology and paleontology of the Baltic region.

WIMANELLA ? INYOENSIS, new species

PLATE 10, FIGURE 4

This species is represented by numerous specimens in the form of casts in a calcareous sandstone. All of the shells are more or less compressed and distorted. Some of those best preserved indicate that the general outline was transverse. A specimen 6 mm. in length has a width of 7 mm.

The most striking feature is the presence of two strong radiating ridges that originate near the beak and extend forward nearly to the frontal margin. These ridges may be the casts of the main vascular sinuses or it may be that they represent ridges on the exterior of the shell, one on each side of the shallow median sinus. At present, with the material before me, I am inclined to the view that they represent the casts of sinuses, and hence the provisional generic reference to *Wimanella*.

Nothing is known with certainty of the outer surface or of the substance of the shell. The interior casts and the matrices of the casts show two strong radiating ridges, the shell substance having apparently been removed and its place lost by the compression of the sediment before its consolidation.

FORMATION AND LOCALITY.—Lower Cambrian: Limestones in Toll Gate Canyon, about 15 miles (24.14 km.) east of White Pine, White Mountain Range, Inyo County, California.

WIMANELLA SHELBYENSIS, new species

PLATE 10, FIGURE 3

All the specimens representing this species in the collection are flattened in the shale to such an extent that very little of the original convexity of the shell is left and only the impression of the shell remains, as the shell substance has been entirely removed, probably by solution. The general form of this species resembles very closely that of *Billingsella ? appalachia* (Walcott) [1905, p. 231]. The casts show a high cardinal area on the ventral valve with a broad delthyrium, and on the dorsal valve a narrow cardinal area with a broad, open delthyrium.

The exterior surface is marked by fine concentric lines and a few stronger varices of growth. A small ventral valve has a length of 8 mm., with a width of 10 mm. A larger one has a length of 18 mm.; width, 22 mm. A small dorsal valve has a length of 10 mm.; width, 13 mm.; and the largest dorsal valve in the collection has a length of 19 mm.; width, 25 mm.

The specimens show no traces of vascular or muscular markings, in this respect resembling *Wimanella anomala* (Walcott) [1905*a*, p. 230] and *Billingsella appalachia.*

This species appears to be the Lower Cambrian representative of *Wimanella anomala,* differing from the latter in having rounded cardinal angles instead of the acute projecting angles so characteristic of *W. anomala. Wimanella shelbyensis* has the same general form as *B. appalachia,* but differs from it in having a smooth surface and in the absence of all traces of radiating ribs. It more nearly resembles *Wimanella simplex* (see p. 101), but differs from the latter in being more transverse, and the cast of the umbonal cavity is relatively smaller.

It is a curious fact that in all the species above mentioned there is no trace of a vascular marking or muscle scar. All the species occur in argillaceous shale and none of them preserve the shell substance. The shells appear to have been macerated and removed by solution, leaving only a cast of the compressed inner or outer surface of the valve.

The associated fossils are *Obolus smithi* (see p. 62), *Micromitra (Paterina) major* (Walcott) [1905*a*, p. 304] *Micromitra (Paterina) williardi* (see p. 60) and numerous fragments of two or three species of *Olenellus.*

FORMATION AND LOCALITY.—Lower Cambrian: Montevallo shale, 4 miles (6.44 km.) south of Helena, Shelby County, Alabama.

WIMANELLA SIMPLEX, new species

PLATE 10, FIGURE 2

The general form of this species is much like that of *Billingsella coloradoensis* (Shumard) [1860, p. 627], except that the beak of the ventral valve rises above the hinge line much as in *B. highlandensis* (Walcott) [1886, p. 119]. The surface of *W. simplex* appears to be smooth, except for a few concentric lines of growth. Nothing is known of the interior except what is shown by the cast of the umbonal cavity. A crushed specimen with the two valves flattened out indicates that the beak of the dorsal valve was slightly elevated above the hinge line. All of the specimens are flattened in shale, and the shell substance has been removed by solution. The material is unsatisfactory, but, as it represents a species of the smooth type from a known horizon in the Middle Cambrian, it is illustrated and given a specific name.

FORMATION AND LOCALITY.—Lower Cambrian: (1) *Shales on Gordon Creek north of Gordon Mountain, 6 miles (9.65 km.) above the South Fork of the Flathead River;* and (2) Wolsey shales, below Gordon Mountain, on Youngs Creek, about 5 miles (8.05 km.) from its junction with Danaher Creek; both in the Lewis and Clark Forest Reserve, Montana. (3) Drift block supposed to have come from the Mount Whyte formation, found on the south slope of Mount Bosworth, a short distance northwest of the Canadian Pacific Railway track, between Stephen and Hector, eastern British Columbia, Canada.

Genus BILLINGSELLA Hall and Clarke [1892*b*, p. 230]

BILLINGSELLA MAJOR, new species

PLATE 10, FIGURES 1 AND 1*a*

In general form and convexity this shell is related to *Billingsella coloradoensis* (Shumard) [1860, p. 627]. It differs from it in being larger and in having coarser radiating ribs. It is the Upper Cambrian representative of the latter species.

FORMATION AND LOCALITY.—Upper Cambrian: Fine-grained, buff-colored sandstone in excavation on Wells' farm, 2 miles (3.22 km.) west of Baraboo, Sauk County, Wisconsin.

BILLINGSELLA MARION, new species

PLATE 10, FIGURE 5

Dorsal valve transverse; beak small, marginal; sides broad, rounded, and merging into the broadly round, almost transverse frontal margin; cardinal line a little shorter than the greatest width of the valve and sloping very slightly from the beak to the outer extremities; on one specimen the cardinal angle is extended slightly; greatest width about midway of the length; mesial furrow narrow at the beak and gradually widening to a broad, deep furrow which divides the valve into two lobes.

Surface smooth with the exception of a few (six or seven) obscure radiating ribs on each lobe. A specimen 10 mm. in width has a length of 6 mm.

OBSERVATIONS.—This species is represented by three specimens of the dorsal valve. They all indicate a thick shell of the *Billingsella salemensis* (Walcott) [1887, p. 190] type. I do not know of a similar form in the Cordilleran Cambrian fauna. It is associated with *Micromitra* (*Paterina*) *stissingensis* (Dwight) [1889, p. 145], a species of *Microdiscus,* and *Ptychoparia,* in a compact gray limestone.

FORMATION AND LOCALITY.—Middle Cambrian: About 1,750 feet (533.4 m.) above the top of the Lower Cambrian, in the oölitic limestones of the Stephen formation [Walcott, 1908*a*, p. 3], below the horizon of the *Ogygopsis* fauna, east side of Mount Stephen, about 3,000 feet (914.4 m.) above the Canadian Pacific Railway track and 3.5 miles (5.63 km.) east of Field, British Columbia, Canada.

EOORTHIS, new genus

Not *Plectorthis* HALL and CLARKE, 1892, Nat. Hist. New York, Paleontology, VIII, Pt. 1, pp. 194–195. (Characterized as a new genus; see below for copy. This genus, as now restricted, is not known to occur in the Cambrian.)

Orthis (*Plectorthis*) WALCOTT [not (Hall and Clarke)], 1905, Proc. U. S. National Museum, XXVIII, pp. 257–259. (Original characterization copied and genus discussed somewhat as below.)

Plectorthis GRABAU and SHIMER (in part) [not (Hall and Clarke)], 1907, North American Index Fossils, II, Bryozoa and Brachiopoda, pp. 250 and 251. (Characterized.)

In their subdivision of the genus *Orthis* Dalman, Messrs. Hall and Clarke [1892*b*, p. 192] restricted the genus *Orthis* to the group of which *Orthis callactis* Dalman is the type, and, among American forms, *Orthis tricenaria* of the Trenton and Hudson faunas. These

forms show the existence of a transverse apical plate in the delthyrium of the ventral valve. The name *Plectorthis* was proposed for a second group, of which *Orthis plicatella* was made the type, and of this the authors [1892*b*, p. 194] say:

"This is a persistent form, which in American faunas, so far as known, is limited to the Trenton and Hudson River formations. While it retains the strong external ribs of the typical *Orthis*, these are not invariably simple (*O. fissicosta* Hall; *O. triplicatella* Meek; *O. æquivalvis* Hall, not Davidson; *O. jamesi* Hall), the cardinal area of the pedicle valve is comparatively low and the valves are subequally convex. In the interior, the character of the muscle scars, dental lamellæ and cardinal process are essentially the same as in Group I (*Orthis*), and the minute structure of the shell appears to be in precise agreement with that of *O. calligramma*, though no evidence of tubulose costæ has been observed. In *Orthis jamesi*, which is placed in this association, there is occasionally a deviation toward the resupinate contour exemplified in the Groups IV (*Orthis subquadrata*) and V (*Orthis sinuata*)."

In the Cambrian faunas I find a group of species intermediate between the typical forms of *Billingsella* and of *Orthis*, as limited by Hall and Clarke [1829*b*, p. 193], which I have referred for a long time to Hall and Clarke's *Plectorthis*, placing that genus as a subgenus of *Orthis*. This Cambrian group of shells, which I now refer to a distinct genus, may be defined as follows, the type of the genus being *Orthis remnicha* Winchell [1886, p. 317]:

DIAGNOSIS.—Shells subquadrate to transversely elongate, with or without median fold and sinus; valves subequally convex. Hinge line straight, usually forming nearly the greatest diameter of the shell. Cardinal extremities broadly angular, rarely acuminate; surface with radiating ribs and striæ which may be crossed by concentric growth lines and striæ. The ribs increase as the shell grows, by interpolation.

The ventral valve has the umbo more or less elevated over a hinge line, the apex acute and usually incurved. The area is rather broad, flat or incurved, and transversely striated. Teeth short and supported by dental plates that extend to the bottom of the valve, bounding a space (pseudospondylium) including the main vascular sinuses and area of attachment of the adductor muscle scars. Delthyrium open or partially closed by a convex deltidium. The adductor muscle scars are included within a narrow median area beneath the umbo on each side of the median line, and the diductors in a more or less flabelliform area outside of the main vascular sinuses. Pedicle scars unknown.

Dorsal valve with low umbo and slightly incurved apex; area well developed with a broad delthyrium. Deltidial cavity with a straight, simple cardinal process. Dental sockets small, with short crura. The adductor muscle scars are small, the anterior being nearer the median ridge, which usually extends forward from the base of the cardinal process.

Shell structure dense, with a minutely granular ground-mass. Sections vertical to the outer surface show a few laminations of growth, but no fine fibers; sections on the plane of the surface show a few coarse irregular fibers resembling matted wood-pulp fibers, and a dense granular ground-mass that is penetrated here and there by irregular openings of varying size. The openings or pores appear to be confined to one or more lamellæ of the shell and not to pass through it from inner to outer surface, as in *Orthis* (*Dalmanella*) *parva* and allied punctate orthoids; the openings are usually indicated by minute scattered dark spots.

TYPE OF GENUS.—*Orthis remnicha* Winchell [1886, p. 317].

OBSERVATIONS.—The Cambrian species referred to *Eoorthis* have relatively thin shells that retain on the interior surfaces but slight traces of the muscle scars and vascular markings, except in the umbonal cavity. *Eoorthis* may be distinguished from *Orthis* (s. s.) by (1) its ribs increasing by interpolation; (2) its strongly defined pseudospondylium; (3) relatively thin shell; and (4) its dense, nonfibrous shell structure. The last three characters also distinguish it from *Plectorthis* and other subgenera of *Orthis*. *Eoorthis* may be considered as the possible connecting line between *Billingsella* and the orthoids of the Ordovician.

The geological range of *Eoorthis* is from the upper portion of the Middle Cambrian through the Upper Cambrian and into the Lower portion of the Ordovician.

Two of the species from strata referred to the Middle Cambrian are represented by material too imperfect for specific description; they occur with *Paradoxides* in Bohemia, and it is not improbable that they will be found to belong to some other genus. The remaining species referred to the Middle Cambrian are *E. wichitensis* (Walcott) [1905*a*, p. 271], which occurs in the upper portion of the Middle Cambrian and base of the Upper Cambrian, and *E. hastingsensis* (Walcott) [1905*a*, p. 263], which occurs in the Middle Cambrian (*Paradoxides* zone).

From the above statements it will be seen that the first representatives of *Eoorthis* in the Cambrian appear in the upper portion of the Middle Cambrian, and that the greater number of species, 21 out of 31, are Upper Cambrian forms.

EOORTHIS NEWBERRYI, new species

PLATE 10, FIGURES 6 AND 6*a*

Shell transversely subelliptical, with the cardinal extremities obtusely angular; valves moderately convex, with the hinge line a little shorter than the greatest width of the valves. The only ventral valve in the collection showing a mesial fold is a small exfoliated shell that is somewhat doubtfully referred to the species. Two of the larger valves in the collection have the posterior margin extended beyond the hinge line, with a short incurved beak; a broad, shallow median sinus begins in front of the umbo and widens to nearly one-third of the width of the valve at the frontal margin. On a shell 5 mm. in length the sinus is very shallow; area unknown. The dorsal valve is almost uniformly convex and without a mesial sinus or fold; the front margin arches upward a little to provide for the extension of the margin of the ventral valve caused by its broad median sinus; beak minute and marginal; area unknown.

Surface marked by concentric lines and ridges of growth and small, rounded, radiating ribs with two or three smaller ribs between each two larger ridges. The shell structure is fibrous and impunctate, as far as can be determined from the material available for study. The largest ventral valve has a length of 14 mm.; width, 18 mm. A dorsal valve 15 mm. in length has a width of 18 mm.

OBSERVATIONS.—In form this species resembles some species of *Eoorthis remnicha* (N. H. Winchell) [1886, p. 317], but in surface characters it is quite unlike any of them.

FORMATION AND LOCALITY.—Upper Cambrian: About 1,100 feet (335.3 m.) above the top of the Middle Cambrian and 125 feet (38.1 m.) below the Lower Ordovician, in the limestone of the St. Charles formation of the Blacksmith Fork Section, about 7 miles (11.27 km.) above the mouth of Blacksmith Fork and 14 miles (22.54 km.) east of Hyrum, Cache County, Utah.

EOORTHIS THYONE, new species

PLATE 10, FIGURES 7 AND 7*a*

In outline and size this species resembles *Eoorthis wichitensis* (Walcott) [1905*a*, p. 271], but in its sharp, uniform, radiating ribs it differs from that and other species having a somewhat similar outline. The ribs radiate from the beak and increase in number by interpolation of new ribs at irregular distances from the beak. Nothing is known of the area of either valve. A cast of the interior of a dorsal valve shows rather large muscle scars.

A large ventral valve has a length of 8 mm.; width, 9 mm. Substance of shell unknown.

OBSERVATIONS.—This species was at first compared with *Nisusia (Jamesella) nautes* (Walcott) [1905*a*, p. 283], but the surface ribs are more regular and less numerous. It also occurs 1,800 feet (548.6 m.) higher in the stratigraphic section than the fauna of *N. (J.) nautes*.

FORMATION AND LOCALITY.—Middle Cambrian: (1) About 2,250 (685.8 m.) above the top of the Lower Cambrian and 2,150 feet (655.3 m.) below the Upper Cambrian, in the gray shaly limestones of the Marjum formation; and (2) *about 2,450 feet (746.8 m.) above the top of the Lower Cambrian and 1,950 feet (594.4 m.) below the Upper Cambrian, in the thin-bedded limestones of the Marjum formation, House Range Section;* both 2.5 miles (4.02 km.) east of Antelope Springs, in ridge surrounding Wheeler Amphitheater, House Range, Millard County, Utah.

EOORTHIS ZENO, new species

PLATE 10, FIGURE 8

In outline the ventral valve of this species is somewhat similar to that of some forms of *Eoorthis remnicha winfieldensis* (Walcott) [1905*a*, p. 270], but it differs in having finer radiating ribs and in its smaller size. It is also much smaller than *Eoorthis newberryi*, and it occurs 4,400 feet lower in the same stratigraphic section. I do not know of any similar form with such regular, fine, sharp, radiating ribs from the Cambrian terrane. The largest ventral valve in the collection has a length of 10 mm.; width, 18 mm.

FORMATION AND LOCALITY.—Middle Cambrian: About 1,100 feet (335.3 m.) above the top of the Lower Cambrian and 3,300 feet (1,005.8 m.) below the Upper Cambrian, in the arenaceous limestone of the Ute formation, in the Blacksmith Fork Section, about 8 miles (12.87 km.) above the mouth of Blacksmith Fork Canyon and 15 miles (24.14 km.) east of Hyrum, Cache County, Utah.

Genus SYNTROPHIA Hall and Clarke [1892*b*, p. 270]

SYNTROPHIA CAMBRIA, new species

PLATE 10, FIGURES 11 AND 11*a*

General form transversely oval, strongly convex, but not rotund. Ventral valve moderately convex, with the frontal margin in adult shells prolonged; a flattened median sinus begins on the umbo and widens to two-thirds the width of the shell in front; area unknown.

Dorsal valve moderately convex except on the median fold, which is rounded but not unusually prominent; area unknown.

Surface marked by a few concentric lines of growth. The largest dorsal valve has a length of 8 mm.; width, 11 mm. A ventral valve 9 mm. in length has a width of 14 mm.

Casts of the interior of the valves indicate that there was a low spondylium formed by a short ridge rising a little distance from the center on each side; this separates an area beneath the umbo not unlike that of the ventral valve of *Billingsella*. There is no trace in either valve of a median septum. The spondylium or chamber appears to have been attached to the bottom of the valves or to have had the shell as its bottom; if this view is correct, a true spondylium had not been developed in this species.

OBSERVATIONS.—In form this species is usually most nearly related to *Syntrophia calcifera* (Billings) [1861*a*, p. 318]. It differs in having a less clearly defined beak and less prominent fold on the dorsal valve. There are many points in common between *Syntrophia cambria* and *S. nundina* (Walcott) [1905*a*, p. 292], but they differ in the shorter beak and sharper median fold of the latter. *Syntrophia cambria* occurs in the Wasatch range about 3,300 feet below the base of the Ordovician, while *S. califera* and *S. nundina* occur in the lower Ordovician. It is the oldest species of the genus and is of interest also on account of being closely related in form to the Ordovician species mentioned.

FORMATION AND LOCALITY.—Middle Cambrian: (1) About 1,100 feet (335.3 m.) above the top of the Lower Cambrian and 3,300 feet (1,005.8 m.) below the Upper Cambrian, in the arenaceous limestones of the Ute formation, Blacksmith Fork Section, about 8 miles (12.87 km.) above the mouth of Blacksmith Fork Canyon and 15 miles (24.14 km.) east of Hyrum; and (2) *same horizon as* (1) *and about 10 miles south of that locality, just south of the south fork of East Fork, east of Cache Valley;* both in Cache County, Utah. (3) About 100 feet (30.5 m.) above the Cambrian quartzites, in shales of Tintic Range Section, near summit of ridge between Mammoth and Eureka, Juab County, Utah.

SYNTROPHIA CAMPBELLI, new species

PLATE 10, FIGURES 9, 9*a–c*

General form rotund, unequally biconvex; hinge line short. Ventral valve moderately convex, exclusive of the prolonged frontal margin; it is depressed toward the front in adult shells by a broad median sinus that disappears on the umbo; area short and divided

midway by a relatively large, open, triangular delthyrium. Dorsal valve convex, with an elevated, relatively narrow median fold that does not extend back to the beak; area short and divided by a strong, open, triangular delthyrium.

Surface marked by concentric striæ and a few strong lines of growth. The largest shell is represented by a dorsal valve that has a length of 12 mm.; width, 14 mm. A ventral valve 7 mm. in length has a width of 11 mm.

Casts of the ventral valve show a spondylium supported on a septum that extended from the beak about one-third the distance to the front margin. The spondylium of the dorsal valve rests directly on the interior of the shell without trace of a supporting median septum.

OBSERVATIONS.—The young shells of this species are almost evenly convex, the fold of the dorsal valve and the sinus of the ventral valve of the adult shell not having developed. The characteristic spondylium of each valve is shown in the youngest shells observed. The general form of *Syntrophia campbelli* is much like that of *Syntrophia rotundata* (Walcott) [1905*a*, p. 293], and somewhat like that of *Huenella texana* (Walcott) [1905*a*, p. 294]. It differs from the former in having the spondylium of the dorsal valve resting on the interior of the shell and not supported on a septum, in this respect resembling the spondylium of *H. texana*. Some shells have a somewhat transverse posterior margin like that of *H. texana*, but the larger number have the broadly acuminate outline of *S. rotundata*. The muscle scars of the dorsal valve, as far as known, are similar to those of *Huenella abnormis* (Walcott) [1905*a*, p. 289].

FORMATION AND LOCALITY.—Upper Cambrian: Knox chert, Bunker Hill, Greenville quadrangle (U. S. G. S.), 6 miles (9.65 km.) northeast of Rogersville, Hawkins County, Tennessee.

SYNTROPHIA ? UNXIA, new species

PLATE 10, FIGURE 10

This species is represented by a single specimen of the ventral valve from which the shell has been removed by weathering. The cast of the spondylium shows it to have been of the same type as that of the ventral valve of *Syntrophia primordialis* (Whitfield) [1878, p. 51] and *S. barabuensis* (A. Winchell) [1864, p. 228], and to have been attached to the interior of the valve without any intervening septum. The elongate rounded form and scarcely percept-

ible median sinus serve to distinguish this species from all described forms.

This is the oldest shell of this type known to me. It occurs 5,465 feet (1,665.7 m.) below the summit of the Cambrian, in the House Range Section. I am not fully satisfied with the generic reference, but with the data available it can not well be referred to *Billingsella* or any other known genus of the Cambrian Brachiopoda.

FORMATION AND LOCALITY.—Middle Cambrian: About 2,250 feet (685.8 m.) above the top of the Lower Cambrian and 2,150 feet (655.3 m.) below the Upper Cambrian, in the gray shaly limestones of the Marjum formation, House Range Section, 2.5 miles (4.02 km.) east of Antelope Springs, in ridge surrounding Wheeler Amphitheater, House Range, Millard County, Utah.

HUENELLA, new genus

This genus is proposed to include the more or less plicate species of the Syntrophiidæ that have heretofore been referred by me to the genus *Syntrophia*. They differ from *Syntrophia* in having a more or less radially plicate surface and sessile or pseudo spondylia instead of free spondylia supported by a median septum. With the possible exception of *Huenella etheridgei* (see below), all of the species are from the Upper Cambrian.

The shell structure is fibrous, with many minute pores.

TYPE.—*Syntrophia texana* Walcott [1905*a*, p. 294].

The generic name is given in recognition of the thorough and valuable work of Dr. F. von Hoyningen-Huene on the "Silurischen Craniaden."

HUENELLA ETHERIDGEI, new species

PLATE 10, FIGURES 13 AND 13*a*

Orthis (or *Orthisina*), sp., ETHERIDGE, 1905, Trans. Roy. Soc. South Australia, XXIX, p. 250, pl. XXV, figs. 9 and 10. (Described as below and discussed. The specimens represented by figures 9 and 10 are redrawn in this paper, pl. 10, figs. 13 and 13*a*.)

Dr. Etheridge describes the ventral valve as follows:

"Subquadrilateral, convex, the greatest convexity at about midway in the length of the valve, the sinus gradually deepening and widening toward the front, and bounded laterally by ill-defined folds, one on either side, the surface sloping away on either side rapidly to the lateral margins and at a very much less angle within the sulcus; there are indications of costæ on the divaricating folds and in the sulcus.

"The hinge features are hidden in matrix, nor is the umbo distinctly visible."

The dorsal valve is described as follows:

"Rotundato-quadrate, the cardinal margin as long as the width of the valve, the surface convex, except on the dorsolateral alations, where it appears to be flattened. There is a central, acute, or pinched-up fold, produced forward, and expanding as it advances. There are indications of the existence of strong, distinct, subradiating costæ.

"Whether or not this is the brachial valve of the species represented by the preceding form, it is, at present, impossible to say; the two occur in the same bed, however."

From the study of the various forms of *Huenella* described herein, I think that the two valves belong to one species, and I take pleasure in naming it after Dr. R. Etheridge, Jr.

FORMATION AND LOCALITY.—Middle (?) Cambrian: Archæocyathinæ white limestone, near Wirrialpa, in the Flinders Range, South Australia.

HUENELLA LESLEYI, new species

PLATE 10, FIGURES 12 AND 12*a*

Only the exterior of the valves of this species is known. In form and outline it is most nearly related to *Huenella texana*. It differs from the latter in being broader in proportion to its length and in having narrow, radiating, rounded ribs over the entire surface.

This is probably the oldest known *Huenella*. *Billingsella coloradoensis* (Shumard) [1860, p. 627] and *Lingulella manticula* (White) [1874, p. 9] occur in the same bed of limestone.

The specific name is given in honor of the late Dr. J. P. Lesley, State geologist of Pennsylvania.

FORMATION AND LOCALITY.—Upper Cambrian: About 200 feet (61 m.) above the Middle Cambrian and 1,025 feet (312.4 m.) below the top of the Upper Cambrian, in the limestones of the St. Charles formation, about 7 miles (11.27 km.) above the mouth of Blacksmith Fork Canyon and 14 miles (22.54 km.) east of Hyrum, Cache County, Utah.

CLARKELLA, new genus

General form rotund, unequally biconvex. Surface smooth or marked by concentric striæ and lines of growth. Ventral valve convex at the umbo and with a strong, broad median sinus; area low and divided by a relatively large delthyrium. Dorsal valve convex at the umbo, which is extended forward into a strong, broad median fold. Cross sections of the valves near the apex and beneath the umbo show a spondylium supported by four or more septa that divide the umbonal cavity into five chambers.

Thin sections of the shell of the type species show it to be fibrous and with many minute pores arranged in lines radiating from the beak to the front and side margins of the valves.

TYPE.—*Polytoechia ? montanensis* Walcott [1905*a*, p. 295].

This genus is known only by the type species from the Lower Ordovician of Montana. It is distinguished from *Polytoechia* Hall and Clarke [1892*b*, p. 239] by an open delthyrium, smooth surface, and presence of septa and spondylium in the dorsal valve. It differs from *Syntrophia* and *Huenella* in having several septa supporting the spondylia, and also from *Huenella* in having a smooth nonplicate surface.

The generic name is given in recognition of the work of Prof. John M. Clarke, of the Geological Survey of New York, in connection with Prof. James Hall, on the fossil Brachiopoda.

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WINCHELL, N. H.

1886. Fourteenth Annual Report of the Geological and Natural History Survey of Minnesota for 1885, 1886, pp. 313–318: New Species of Fossils. (Referred to on pp. 103, 104, 105.)

DESCRIPTION OF PLATE 7

f. = flexure line of area. *j.* = anterior lateral muscle scar.
h. = central muscle scar. *k.* = middle lateral muscle scar.
i. = transmedian muscle scar. *l.* = outside lateral muscle scar.

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Mickwitzia occidens, new species 54

FIG. 1. View of the type specimen from Lower Cambrian shale, northeast of Silver Peak Mill, Silver Peak quadrangle, Esmeralda County, Nevada, showing the outer and inner surface of the outer layer. U. S. National Museum Catalogue No. 51518.

Mickwitzia pretiosa, new species 54

FIG. 2. Top view of the type specimen from the Lower Cambrian Eophyton sandstones at Lugnås, Vestergotland, Sweden. U. S. National Museum Catalogue No. 51523.

Micromitra haydeni, new species 55

FIG. 3. Top view of type specimen of ventral valve. U. S. National Museum Catalogue No. 51437*a*.

3*a*. Posterior view of ventral valve. U. S. National Museum Catalogue No. 51437*b*.

The specimens represented by Figs. 3 and 3*a* are from the Middle Cambrian limestones of the Langston formation in Two Mile Canyon, southeast of Malad, Oneida County, Idaho.

Micromitra (*Iphidella*) *louise,* new species 56

FIG. 4. Top view of type specimen of ventral valve from the Lower Cambrian shales of the Lake Louise formation, at Lake Louise, south of Laggan, Alberta. U. S. National Museum Catalogue No. 51401*a*.

4*a*. Side view of associated ventral valve. U. S. National Museum Catalogue No. 51401*b*.

Micromitra (*Iphidella*) *nyssa,* new species 57

FIG. 5. Top view of type specimen of ventral valve from Middle Cambrian shales between Gordon Mountain and Cardinal Peak, Ovando quadrangle, Powell County, Montana. U. S. National Museum Catalogue No. 51441*a*.

Micromitra (*Paterina*) *wapta,* new species 59

FIG. 6. Top view of type specimen of ventral valve from a drift block of Lower Cambrian shale, slope of Mt. Bosworth, British Columbia. U. S. National Museum Catalogue No. 51402*a*.

Micromitra (*Paterina*) *williardi,* new species 60

FIG. 7. Top view of type specimen of ventral valve from the Lower Cambrian Montevallo shale, .25 mile (.40 km.) northeast of Helena, Shelby County, Alabama. U. S. National Museum Catalogue No. 51482*a*.

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Micromitra (Paterina) stuarti, new species..... 58

FIGS. 8 and 8*a*. Top and posterior views of type specimen of ventral valve from the Middle Cambrian limestones of the Ute formation, Blacksmith Fork Canyon, Cache County, Utah. U. S. National Museum Catalogue No. 51485*a*.

Obolus smithi, new species..... 62

FIG. 9. Exterior of a slightly distorted dorsal valve. U. S. National Museum Catalogue No. 51611*a*.

9*a*. Cast of the interior of a dorsal valve. U. S. National Museum Catalogue No. 51611*b*.

The specimens represented by Figs. 9 and 9*a* are from Lower Cambrian Montevallo shale, .125 mile (.20 km.) northeast of Helena, Shelby County, Alabama.

Obolus parvus, new species..... 61

FIG. 10. Exterior of ventral valve. U. S. National Museum Catalogue No. 51400*a*.

10*a*. Exterior of dorsal valve. U. S. National Museum Catalogue No. 51400*b*.

The specimens represented by Figs. 10 and 10*a* are from a drift block of Lower Cambrian shale on the slope of Mt. Bosworth, British Columbia.

Obolus membranaceous, new species..... 61

FIG. 11. Type specimen showing cast of ventral valve flattened in the Middle Cambrian shales of the Eldon formation, northwest of Mt. Bosworth, British Columbia. U. S. National Museum Catalogue No. 53674*a*.

Obolus (Westonia) elongatus, new species..... 68

FIG. 12. Type specimen showing cast of ventral valve from Middle Ordovician shales in Wasatch Canyon, north of Brigham, Box Elder County, Utah. U. S. National Museum Catalogue No. 51722*a*.

Obolus (Westonia) notchensis, new species..... 69

FIG. 13. Type specimen showing exterior of partially exfoliated ventral valve from Lower Ordovician limestones on Notch Peak, House Range, Millard County, Utah. U. S. National Museum Catalogue No. 51731*a*.

Obolus (Westonia) dartoni, new species..... 67

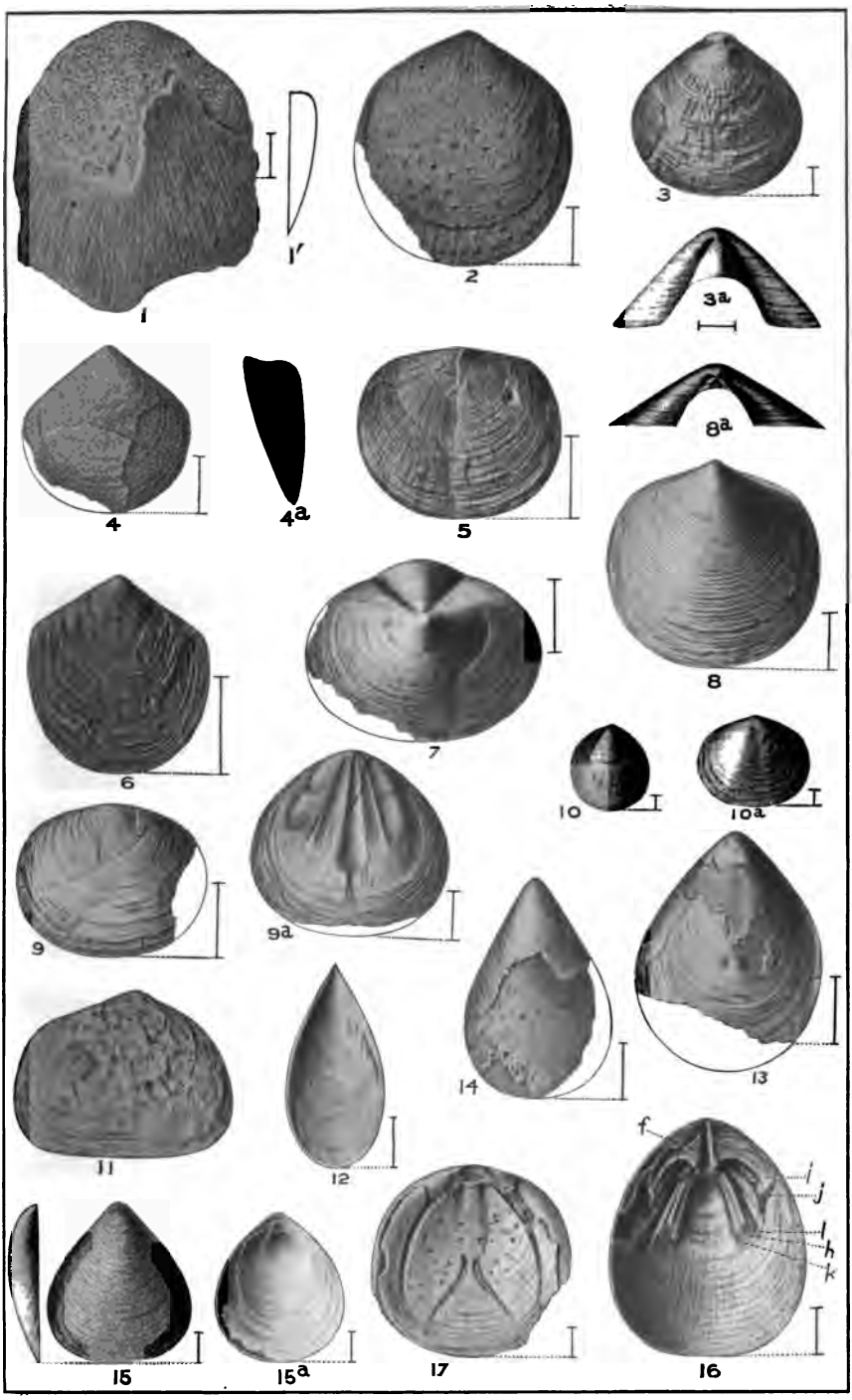
FIG. 14. Type specimen showing exterior of ventral valve from Middle Cambrian sandstones west of Garfield Peak, Natrona County, Wyoming. U. S. National Museum Catalogue No. 51683*a*.

Obolus (Fordinia) gilberti, new species..... 65

FIG. 15. Top and side views of a ventral valve. U. S. National Museum Catalogue No. 51946*a*.

15*a*. Interior of a ventral valve. U. S. National Museum Catalogue No. 51946*b*.

The specimens represented by figures 15 and 15*a* are from Middle Cambrian limestones of the Marjum formation, south of Marjum Pass, House Range, Millard County, Utah.



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Obolus (Fordinia) perfectus, new species..... 65

FIG. 16. Type specimen showing interior of ventral valve from Middle Cambrian shaly limestones of the Weeks formation, south of Marjum Pass, House Range, Millard County, Utah. U. S. National Museum Catalogue No. 51947*a*.

Obolus wortheni, new species..... 63

FIG. 17. Type specimen showing interior of dorsal valve from the Upper Cambrian limestones of the St. Charles formation in Two Mile Canyon, southeast of Malad, Oneida County, Idaho. U. S. National Museum Catalogue No. 51638*a*.

DESCRIPTION OF PLATE 8

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a. = area.
cf. = cardinal muscle scar.
F. = foramen.
F'. = cast of foraminal tube.
h. = central muscle scar.
i. = transmedian muscle scar.
j. = anterior lateral muscle scar.
vs. = vascular sinus.

Obolus (*Westonia*) *wasatchensis*, new species..... 69

FIG. 1. Partially exfoliated ventral valve from a drift block supposed to have come from a Middle Cambrian horizon 1,700 feet (518.2 m.) above the Cambrian quartzitic sandstones, Wasatch Canyon, 5 miles (8.05 km.) north of Brigham, Box Elder County, Utah. U. S. National Museum Catalogue No. 51733.

1*a*. Exterior of a dorsal valve from the Middle Cambrian shales of the Bloomington formation, Blacksmith Fork Canyon, Cache County, Utah. U. S. National Museum Catalogue No. 51734*a*.

Dicellomus parvus, new species..... 76

FIG. 2. Interior of dorsal valve. U. S. National Museum Catalogue No. 52523*a*.

2*a*. Interior of dorsal valve. U. S. National Museum Catalogue No. 52523*b*.

The specimens represented by Figs. 2 and 2*a* are from Middle Cambrian limestones 2.5 miles (40.2 km.) southwest of Yen-chuang, Sin-t'ai District, Shan-tung, China.

Dicellomus prolificus, new species..... 77

FIG. 3. Exterior of ventral valve. U. S. National Museum Catalogue No. 51925*a*.

3*a*. Exterior of dorsal valve. U. S. National Museum Catalogue No. 51925*b*.

The specimens represented by Figs. 3 and 3*a* are from Middle Cambrian limestones of the Marjum formation, south of Marjum Pass, House Range, Millard County, Utah.

Lingulella (*Lingulepis*) *acuminata sequens*, new variety..... 72

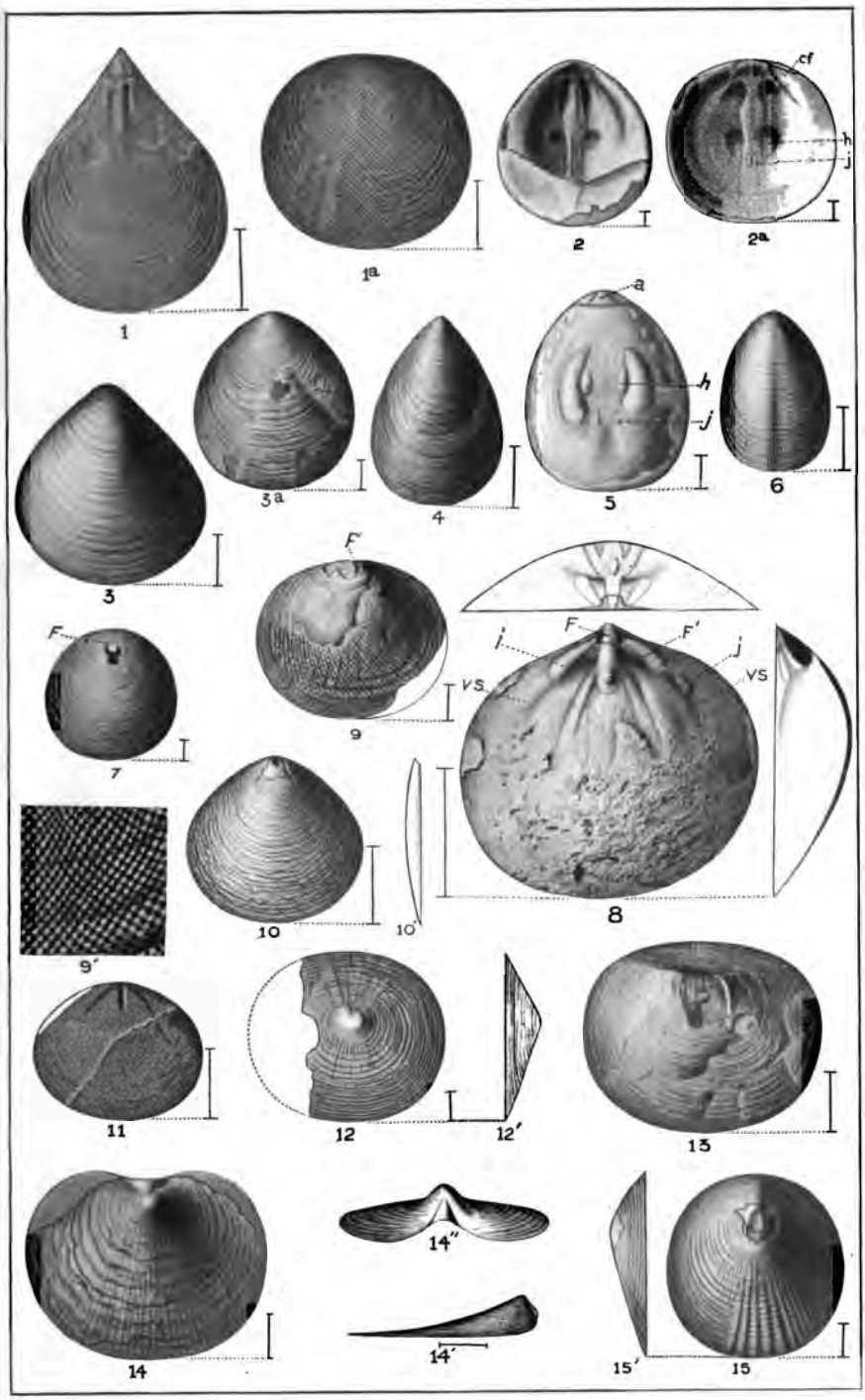
FIG. 4. Exterior of type specimen of ventral valve from Ordovician sandstone, near Ticonderoga, Essex County, New York. U. S. National Museum Catalogue No. 53675*a*.

Lingulella texana, new species..... 71

FIG. 5. Type specimen showing cast of the interior of a dorsal valve from Middle Cambrian limestones on Morgan Creek, Burnet County, Texas. U. S. National Museum Catalogue No. 51806.

Lingulella buttsi, new species..... 70

FIG. 6. Type specimen showing exterior of a dorsal valve from Upper Cambrian limestones, near Kimbrel, Bibb County, Alabama. U. S. National Museum Catalogue No. 51779.



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Dearbornia clarki, new species..... 78

FIG. 7. Type specimen showing cast of the interior of a ventral valve from the Middle Cambrian Yogo limestone on the North Fork of the Dearborn River, Lewis and Clark Forest Reserve, Montana. U. S. National Museum Catalogue No. 52214*a*.

Trematobolus excelsis, new species..... 80

FIG. 8. Type specimen showing cast of the interior of a ventral valve with posterior and side outlines, from Lower Cambrian limestones 2–3 miles (3.22–4.83 km.) east-northeast of Waucoba Springs, Inyo County, California. U. S. National Museum Catalogue No. 52208*a*.

Acrothele bellapunctata, new species..... 82

FIG. 9. Type specimen showing exterior of a partially exfoliated, crushed ventral valve from Lower Cambrian shales at Ringsaker, Province of Hedemarken, Norway. U. S. National Museum Catalogue No. 51972*a*.

9′. Enlargement of a portion of the surface of Fig. 9.

Acrothele artemis, new species..... 82

FIG. 10. Type specimen showing interior of a crushed ventral valve from Middle Cambrian limestones of the Langston formation, in Two Mile Canyon, southeast of Malad, Oneida County, Idaho. U. S. National Museum Catalogue No. 51969.

Acrothele bergeroni, new species..... 83

FIG. 11. Type specimen showing cast of the interior of a dorsal valve from Middle Cambrian shales in Montagne Noire, Coulouma, Department of Herault, France. U. S. National Museum Catalogue No. 51975*a*.

Acrothele borgholmensis, new species..... 84

FIG. 12. Top and side views of type specimen of broken ventral valve from the Upper Cambrian Ceratopyge slate, at Borgholm, Oeland Island, Sweden. U. S. National Museum Catalogue No. 51974*a*.

Acrothele levisensis, new species..... 85

FIG. 13. Top view of type specimen of crushed ventral valve from the Lower Ordovician Levis shales, at Point Levis, Quebec, Canada. Collections of the Geological Survey of Canada.

Acrothele spurri, new species..... 86

FIG. 14. Top view of type specimen of ventral valve from Lower Cambrian limestones of the Pioche formation, near Pioche, Lincoln County, Nevada. U. S. National Museum Catalogue No. 15344*a*.

14′ and 14″. Side and posterior views of an associated ventral valve. U. S. National Museum Catalogue No. 15344*b*.

Acrothele subsidua hera, new variety..... 87

FIG. 15. Top and side views of type specimen of ventral valve from Lower Cambrian limestones of the Pioche formation, near Pioche, Lincoln County, Nevada. U. S. National Museum Catalogue No. 52024.

DESCRIPTION OF PLATE 9

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ac. = apical callosity.
cl. = cardinal muscle scars.
fp. = pseudo pedicle groove.
h. = central muscle scars.
s. = median septum.
vs. = vascular sinuses.

Acrotreta ophirensis descendens, new variety 95

FIG. 1. Top, side, and back views of type specimen of ventral valve from Middle Cambrian shaly limestones of the Weeks formation, south of Marjum Pass, House Range, Millard County, Utah. U. S. National Museum Catalogue No. 52143*a*.

1*a*. Interior of an associated dorsal valve. U. S. National Museum Catalogue No. 52143*b*.

Acrotreta marjumensis, new species 94

FIG. 2. Top, side, and back views of a ventral valve. U. S. National Museum Catalogue No. 52116*a*.

2*a*. Interior of an associated dorsal valve. U. S. National Museum Catalogue No. 52116*b*.

The specimens represented by Figs. 2 and 2*a* are from the Middle Cambrian limestones of the Marjum formation, south of Marjum Pass, House Range, Utah.

Acrotreta ulrichi, new species 96

FIG. 3. Top, back, and side views of type specimen of ventral valve from the Middle Cambrian limestones of the Reagan formation, east of Homer, Woods County, Oklahoma. U. S. National Museum Catalogue No. 52180.

Acrotreta bellatula, new species 93

FIG. 4. Top, side, and back views of a ventral valve. U. S. National Museum Catalogue No. 52072*a*.

4*a*. Interior of a ventral valve. U. S. National Museum Catalogue No. 52072*b*.

4*b*. Cast of the interior of a dorsal valve. U. S. National Museum Catalogue No. 52072*c*.

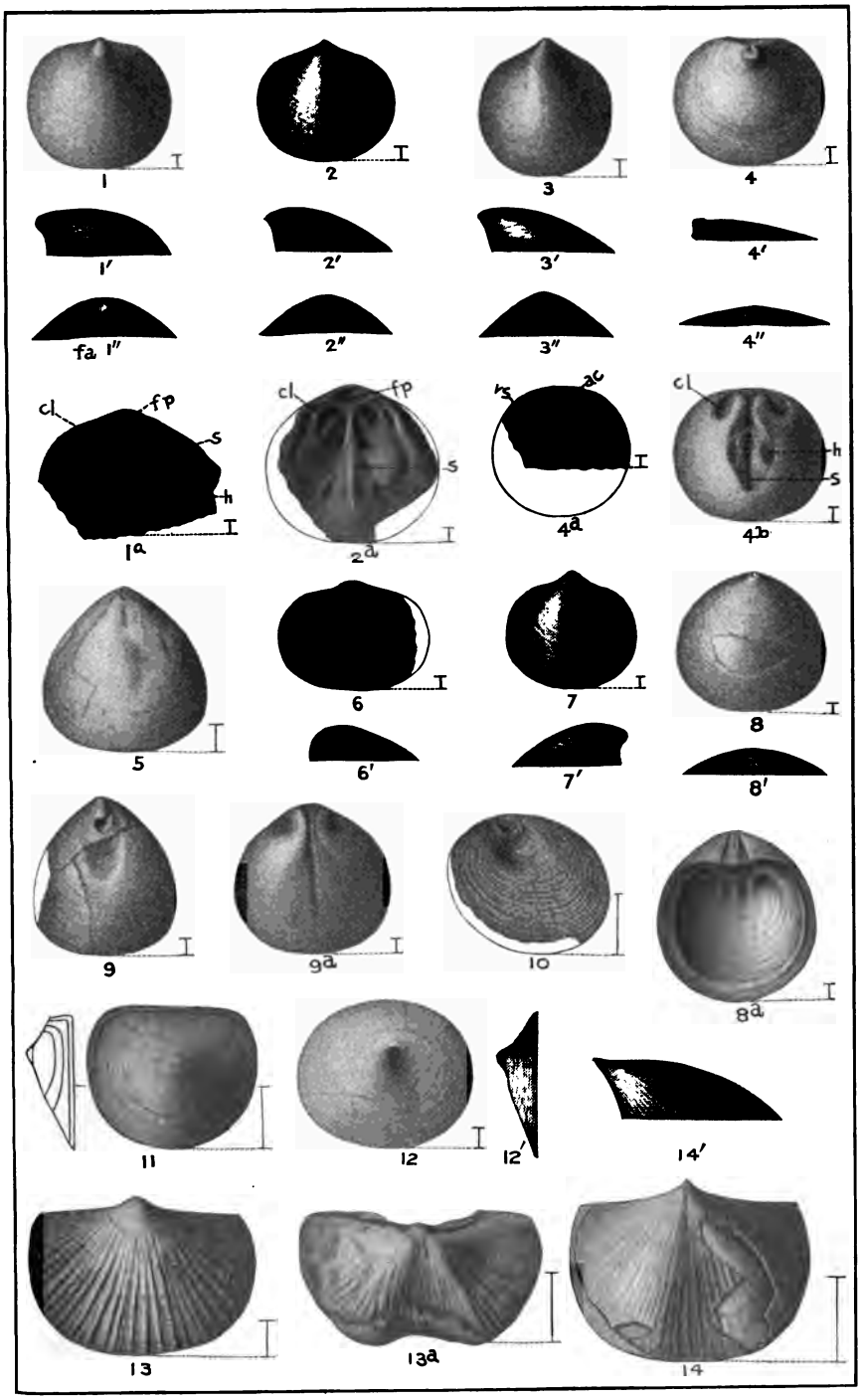
The specimens represented by Figs. 4, 4*a–b* are from Middle Cambrian limestones of the Marjum formation, south of Marjum Pass, House Range, Millard County, Utah.

Acrotreta rudis, new species 95

FIG. 5. Type specimen, an exfoliated and crushed ventral valve from Middle Cambrian shales, 3.5 miles (5.63 km.) from Rogersville, on the road to Melindy's Ferry, Hawkins County, Tennessee. U. S. National Museum Catalogue No. 52111.

Linnarssonella transversa, new species 92

FIG. 6. Top and side views of type specimen of ventral valve from Upper Cambrian shales of the Orr formation, south of Marjum Pass, House Range, Millard County, Utah. U. S. National Museum Catalogue No. 52201.



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Linnarssonella nitens, new species..... 91

FIG. 7. Top and side views of type specimen of ventral valve from Upper Cambrian limestones of the Orr formation, south of Marjum Pass, House Range, Millard County, Utah. U. S. National Museum Catalogue No. 52198*a*.

Linnarssonella modesta, new species..... 90

FIG. 8. Top and back view of a ventral valve. U. S. National Museum Catalogue No. 53679.

8*a*. Interior of a ventral valve. U. S. National Museum Catalogue No. 52197*a*.

The specimens represented by Figs. 8 and 8*a* are from Upper Cambrian shales of the Orr formation, south of Marjum Pass, House Range, Millard County, Utah.

Linnarssonella urania, new species..... 92

FIG. 9. Exterior of a ventral valve. U. S. National Museum Catalogue No. 52202*a*.

9*a*. Cast of the interior of a dorsal valve. U. S. National Museum Catalogue No. 52202*b*.

The specimens represented by 9 and 9*a* are from Middle Cambrian limestones in Big Cottonwood Canyon, southeast of Salt Lake City, Utah.

Acrothele yorkensis, new species..... 88

FIG. 10. Type specimen showing exterior of a crushed ventral valve from Middle Cambrian shales at York, York County, Pennsylvania. U. S. National Museum Catalogue No. 52031*a*.

Acrothele woodworthi, new species..... 88

FIG. 11. Top view and side outline of a cast of the type specimen of a ventral valve from the Lower Cambrian Nahant limestone, at Nahant, Essex County, Massachusetts. U. S. National Museum Catalogue No. 52030 (cast).

Acrothele turneri, new species..... 87

FIG. 12. Top and side views of type specimen of ventral valve from Middle Cambrian shales south of Emigrant Peak, Esmeralda County, Nevada. U. S. National Museum Catalogue No. 52028*a*.

Nisusia rara, new species..... 97

FIG. 13. Exterior of a ventral valve. U. S. National Museum Catalogue No. 52295*a*.

13*a*. Cast of the interior of a dorsal valve. U. S. National Museum Catalogue No. 52295*b*.

The specimens represented by Figs. 13 and 13*a* are from the Middle Cambrian Spence shales in Spence Gulch, west of Montpelier, Bear Lake County, Idaho.

Nisusia (Jamesella) lowi, new species..... 98

FIG. 14. Top and side views of type specimen of ventral valve from Lower Cambrian limestones 5 feet (1.5 m.) below the top of the Mt. Whyte formation, just above the tunnel, north shoulder of Mt. Stephen, 3 miles (4.83 km.) east of Field, British Columbia. U. S. National Museum Catalogue No. 53677*a*.

DESCRIPTION OF PLATE 10

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a. = cardinal area.
a'. = cast of umbonal cavity.

Billingsella major, new species 101
FIG. 1. Cast of the interior of a broken ventral valve. U. S. National Museum Catalogue No. 52256*a*.
1*a*. Cast of a dorsal valve. U. S. National Museum Catalogue No. 52256*b*.
The specimens represented by Figs. 1 and 1*a* are from Upper Cambrian sandstones 2 miles (3.22 km.) west of Baraboo, Sauk County, Wisconsin.

Wimanella simplex, new species 101
FIG. 2. Type specimen showing exterior of ventral valve from Lower Cambrian shales, 6 miles (9.66 km.) up Gordon Creek from South Fork of Flathead River, Lewis and Clark Forest Reserve, Montana. U. S. National Museum Catalogue No. 52278*a*.

Wimanella shelbyensis, new species 100
FIG. 3. Type specimen showing exterior of compressed ventral valve from Lower Cambrian Montevallo shale, 4 miles (6.44 km.) south of Helena, Shelby County, Alabama. U. S. National Museum Catalogue No. 52272*a*.

Wimanella ? inyoensis, new species 102
FIG. 4. Type specimen showing cast of the interior of ventral valve from Lower Cambrian limestone in Toll Gate Canyon, White Mountain Range, Inyo County, California. U. S. National Museum Catalogue No. 52255*a*.

Billingsella marion, new species 99
FIG. 5. Type specimen showing cast of the interior of ventral valve from Middle Cambrian limestones of Stephen formation on Mount Stephen, British Columbia. U. S. National Museum Catalogue No. 53676*a*.

Hoorthis newberryi, new species 105
FIG. 6. Exterior of ventral valve. U. S. National Museum Catalogue No. 52350*a*.
6*a*. Exterior of dorsal valve. U. S. National Museum Catalogue No. 52350*b*.
The specimens represented by Figs. 6 and 6*a* are from Upper Cambrian limestones of the St. Charles formation, in Blacksmith Fork Canyon, east of Hyrum, Cache County, Utah.

Hoorthis thyone, new species 105
FIGS. 7 and 7*a*. Exterior of dorsal valves. U. S. National Museum Catalogue Nos. 52377*a* and 52377*b*.
The specimens represented by Figs. 7 and 7*a* are from Middle Cambrian limestones of the Marjum formation, east of Antelope Springs, House Range, Millard County, Utah.

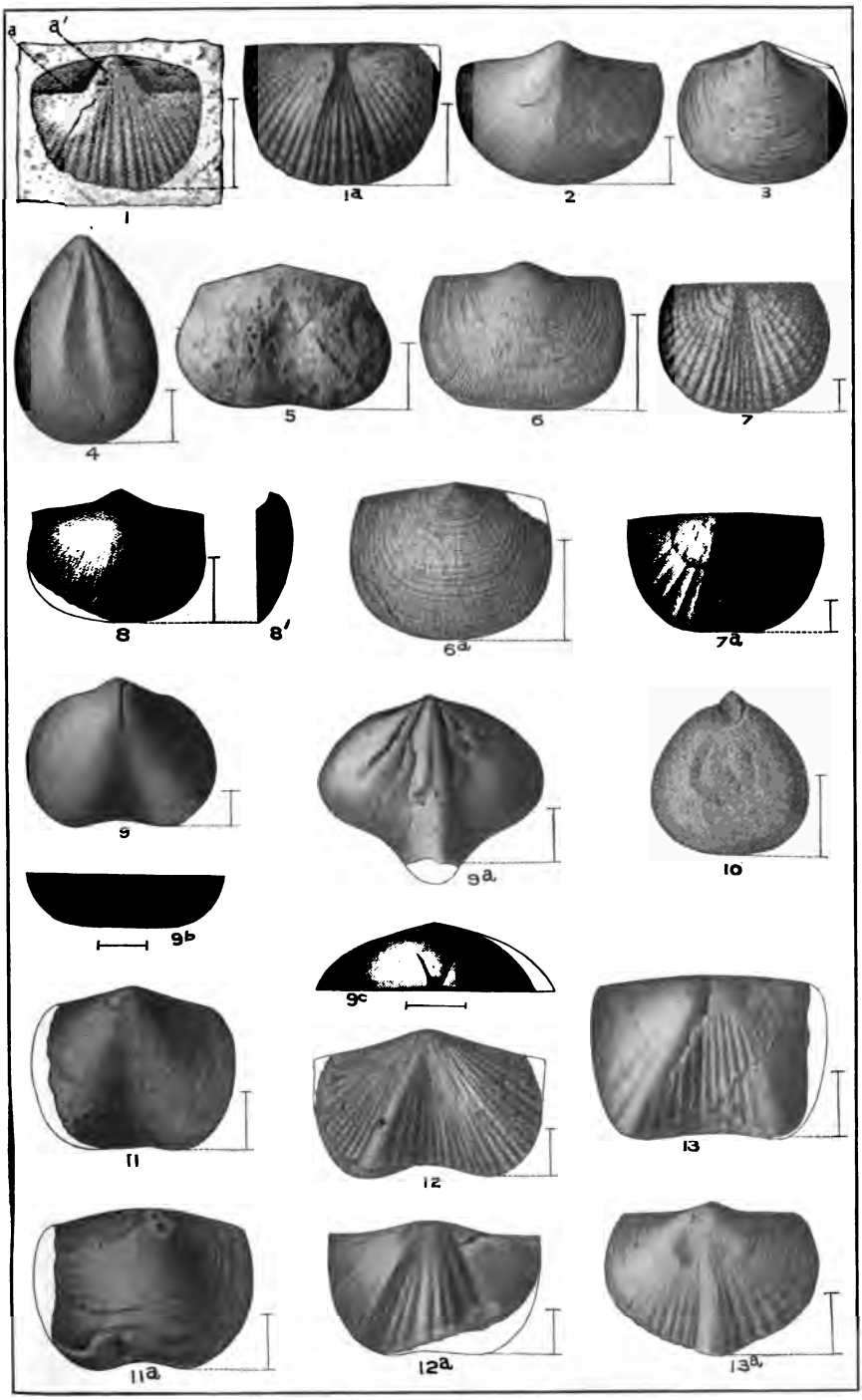

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FIG. 8. Exterior view and side outline of type specimen of ventral valve from Middle Cambrian limestones of the Ute formation, in Blacksmith Fork Canyon, east of Hyrum, Cache County, Utah. U. S. National Museum Catalogue No. 52397*a*.

Syntrophia campbelli, new species..... 107

FIG. 9. Cast of interior of ventral valve. U. S. National Museum Catalogue No. 52480*a*.

9*a*. Cast of the interior of a dorsal valve. U. S. National Museum Catalogue No. 52480*b*.

9*b*. Section of the beak of a ventral valve, showing septum and spondylium. U. S. National Museum Catalogue No. 52480*c*.

9*c*. Cast of the interior of the posterior portion of the dorsal valve, showing the cast of a section of the spondylium. U. S. National Museum Catalogue No. 52480*d*.

The specimens represented by Figs. 9, 9*a-c* are from the Upper Cambrian Knox chert at Bunker Hill, northeast of Rogersville, Tennessee.

Syntrophia ? unxia, new species..... 108

FIG. 10. Type specimen showing an imperfect cast of the interior of a ventral valve from Middle Cambrian shaly limestones of the Marjum formation, east of Antelope Springs, House Range, Millard County, Utah. U. S. National Museum Catalogue No. 52499.

Syntrophia cambria, new species..... 106

FIG. 11. Exterior of ventral valve. U. S. National Museum Catalogue No. 52477*a*.

11*a*. Exterior of dorsal valve. U. S. National Museum Catalogue No. 52478.

The specimens represented by Figs. 11 and 11*a* are from Middle Cambrian limestones of the Ute formation in East Fork Canyon, east of Cache Valley, Utah.

Huenella lesleyi, new species..... 110

FIG. 12. Exterior of ventral valve. U. S. National Museum Catalogue No. 52481*a*.

12*a*. Exterior of dorsal valve. U. S. National Museum Catalogue No. 52481*b*.

The specimens represented by Figs. 12 and 12*a* are from Upper Cambrian limestones of the St. Charles formation in Blacksmith Fork Canyon, east of Hyrum. Cache County, Utah.

Huenella etheridgei, new species..... 109

FIG. 13. Partial cast of interior of ventral valve.

13*a*. Partial cast of interior of dorsal valve.

The specimens represented by Figs. 13 and 13*a* are from Middle Cambrian limestones near Wirrialpa, in the Flinders Range, South Australia. Collections of the University of Adelaide, South Australia. Casts in U. S. National Museum, Catalogue Nos. 53678*a* and 53678*b*.

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[1] Brackets are used in this connection to indicate that while the author, whose name is thus bracketed, described a fossil under the name which precedes his own, he was not the first to describe a fossil under that name.

[2] The number in heavy-faced type refers to the page upon which the species is described.

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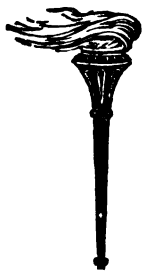

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No. 4.—CLASSIFICATION AND TERMINOLOGY OF THE CAMBRIAN BRACHIOPODA

WITH TWO PLATES

BY

CHARLES D. WALCOTT

UNIVERSITY OF CALIFORNIA
DEPARTMENT OF
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INTRODUCTION

My study of the Cambrian Brachiopoda has advanced so far that it is decided to publish, in advance of the monograph,[2] a brief outline of the classification, accompanied by (*a*) a schematic diagram of evolution and scheme of classification; (*b*) a note, with a diagram, on the development in Cambrian time; (*c*) a note on the structural characters of the shell, as this profoundly affects the classification; and (*d*) a section on the terminology used in the monograph. The monograph, illustrated by 104 quarto plates and numerous text figures, should be ready for distribution in the year 1909.

SCHEMATIC DIAGRAM OF EVOLUTION

In order to formulate, as far as possible, in a graphic manner a conception of the evolution and lines of descent of the Cambrian Brachiopoda, a schematic diagram (see plate 11) has been prepared for reference. It is necessarily tentative and incomplete, but it will serve to point out my present conceptions of the lines of evolution of the various genera, and it shows clearly the very rapid development of the primitive Atrematous genera in early Cambrian time.

[1] Published by permission of the Director of the U. S. Geological Survey.

[2] Monograph LI, U. S. Geological Survey.

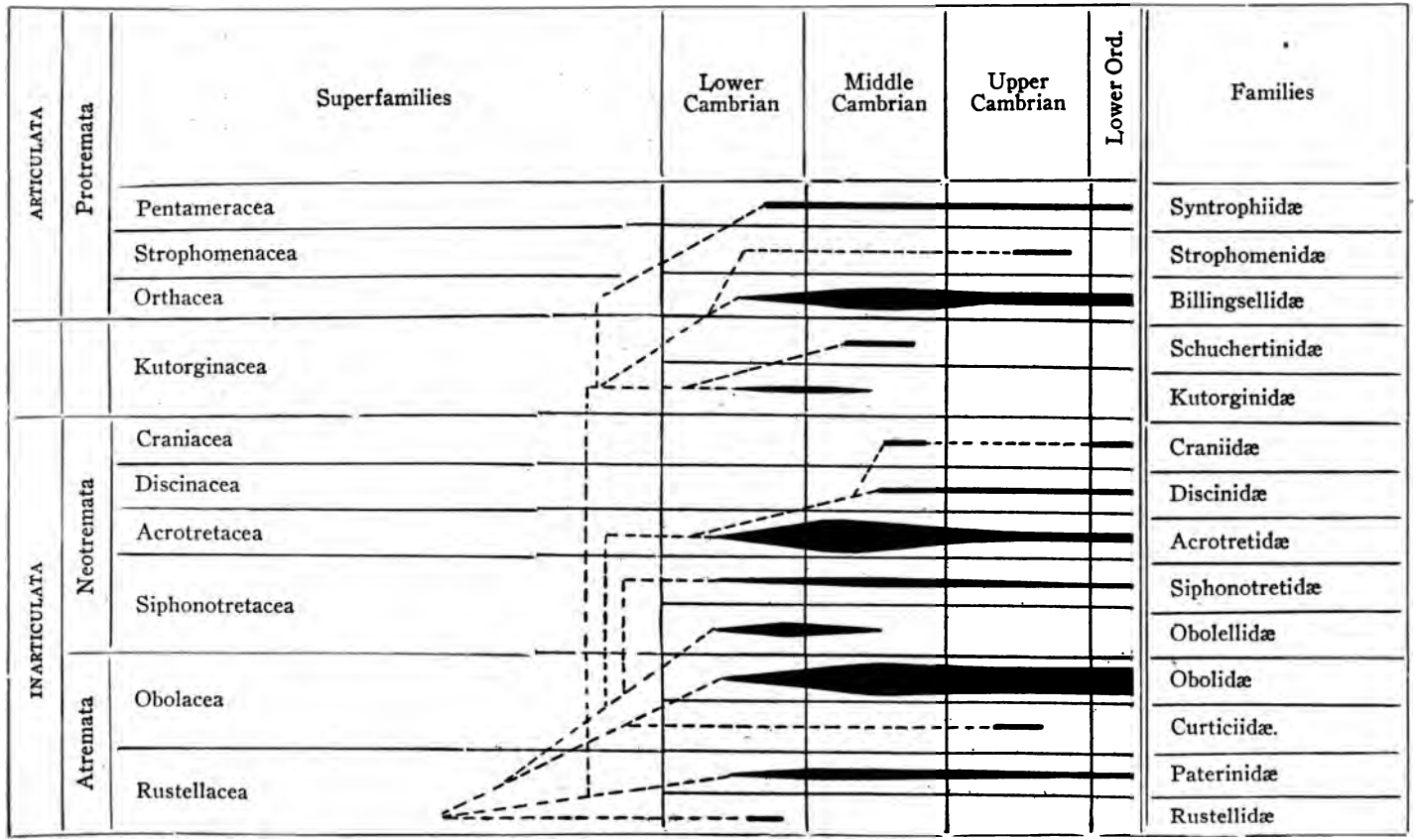
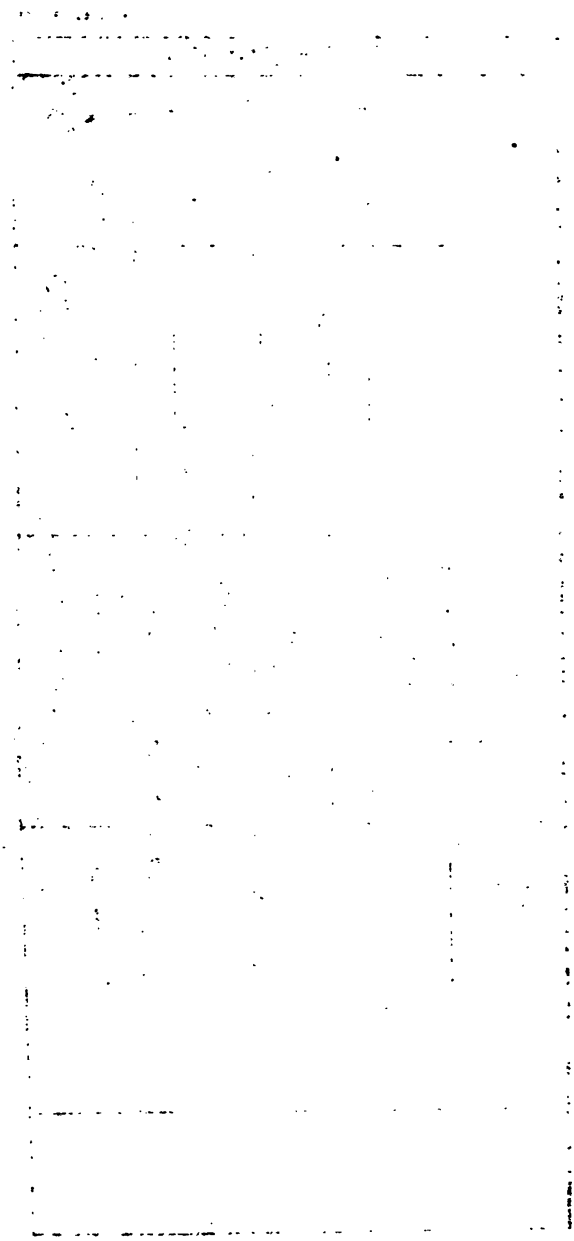


FIG. 1.—Diagram Illustrating Known Distribution of Families in Cambrian Strata.



DEVELOPMENT IN CAMBRIAN TIME

We do not know of any brachiopoda in strata older than that containing the *Olenellus* or Lower Cambrian fauna. That such existed in pre-Cambrian time seems almost certain when the advanced stage of development of some of the earliest known forms is considered.

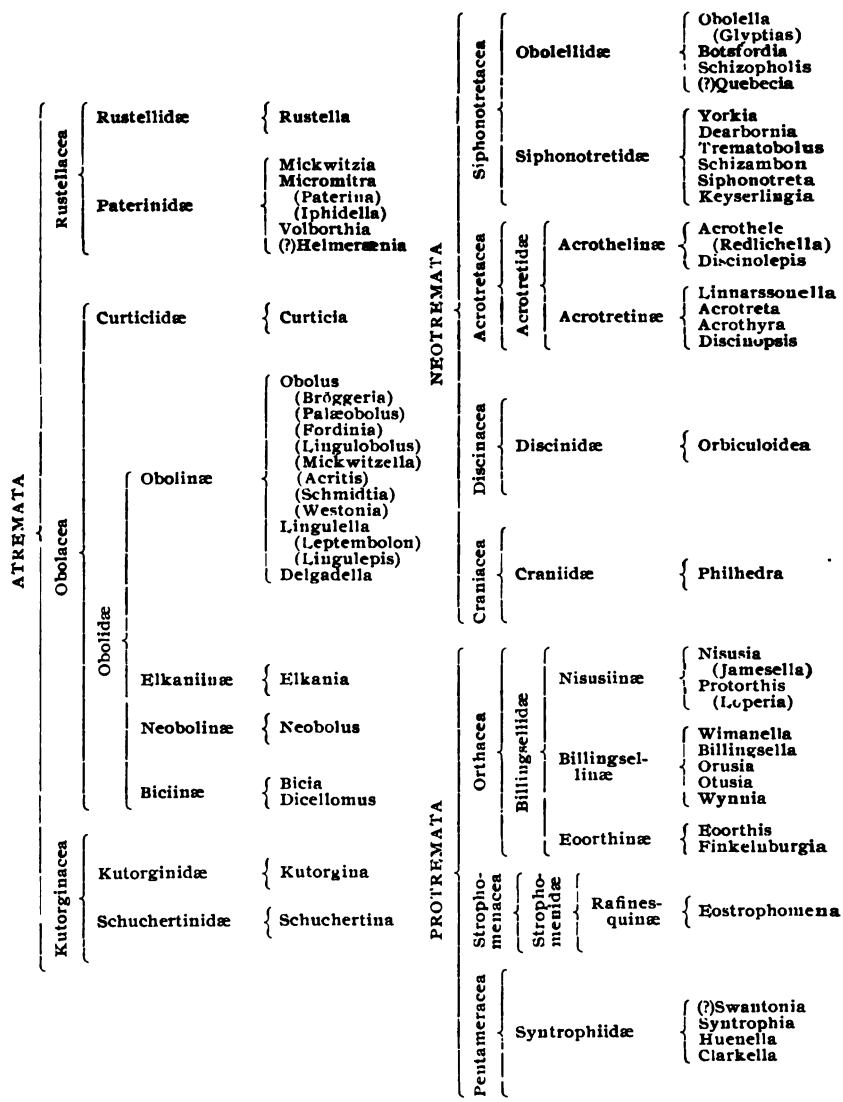
In the preceding diagram the known occurrence of the families of brachiopoda in strata of Cambrian age is graphically shown. The diagram is based on the data contained in tables prepared for the monograph giving a summary by families. The Obolidæ, with 7 genera, 9 subgenera, 183 species, and 17 varieties, has the greatest development, and the family continues into the base of the Ordovician with 2 genera, 7 subgenera, and 36 species. The Acrotretidæ has 6 genera, 1 subgenus, 93 species, and 19 varieties, with the greatest development in the Middle Cambrian and with a smaller representation in the Lower Ordovician. The Billingsellidæ, with 9 genera, 2 subgenera, 95 species, and 12 varieties, has a strong development in the upper Middle Cambrian and passes into the Ordovician, where it disappears. The three families mentioned include about 48 per cent of the genera, 80 per cent of the subgenera, 81 per cent of the species, and 81 per cent of the varieties included in the Cambrian brachiopoda. The development of genera of the remaining families containing 3 genera or more is as follows: Paterinidæ, 4; Obolellidæ, 4; Siphonotretidæ, 6; Syntrophiidæ, 3; or 17 genera of the 24 outside of the Obolidæ, Acrotretidæ, and Billingsellidæ, which contain 23 genera. The remaining 7 families include 7 genera.

Of the 46 genera from the Cambrian, 20 occur in the Lower Cambrian, 31 in the Middle Cambrian, and 23 in the Upper Cambrian.

SCHEME OF CLASSIFICATION

In order that we may have a graphic illustration to aid in description, the following table is inserted. The ordinal classification of Beecher [1891], with emendations, is taken as the basis for the orders, while the arrangement of superfamilies is practically that of Schuchert [1897], with such emendations and additions as greater information has rendered necessary. Dr. Charles Schuchert has been most helpful in discussion and criticism of this scheme of classification, and I am also indebted to Mr. E. O. Ulrich for a discussion of the classification of the Protremata. Due acknowledgment will be made in the monograph to many persons who have aided in various ways in making the monograph much more complete and useful than it otherwise would have been.

TABLE OF CLASSIFICATION.



Order ATREMATA Beecher, 1891 (emend)

Primitive inarticulate, corneous or calcareo-phosphatic Brachiopoda with the pedicle emerging more or less freely between the two valves. Growth takes place in general around the anterior and lateral margins. Specialized forms show tendency to develop rudimentary articulation. Delthyrium originally unmodified, in later genera modified by pseudodeltidia and pseudochilidia, or by thick-

ened, striated, and more or less furrowed or even cleft vertical cardinal margins, the ventral cleft in most specialized forms tending to enclose the pedicle and finally restrict it to the ventral valve; when completely so the genera are referred to the order Neotremata.

Superfamily RUSTELLACEA Walcott, new

Primitive, thick-shelled, corneous or calcareo-phosphatic Atremata developing more or less of pseudodeltidia and pseudochilidia.

Family RUSTELLIDÆ Walcott, new

Primitive Rustellacea with the delthyrium small, open, and not much modified by pseudodeltidia or pseudochilidia. Muscle scars and vascular sinuses not well defined in the shell.

Rustella

Family PATERINIDÆ Schuchert, 1893 (emend)

Progressive Rustellacea with the delthyrium more or less closed by pseudodeltidia or pseudochilidia.

Mickwitzia
Micromitra
(*Paterina*)
(*Iphidella*)
Volborthia
(?) *Helmersenia*

Superfamily OBOLACEA Schuchert, 1896 (emend)

Derived (in Rustellacea), progressive, thick-shelled, calcareo-phosphatic or corneous Atremata without pseudodeltidia and pseudochilidia. Rounded or linguloid in outline, more or less lens-shaped and fixed by a short pedicle throughout life to extraneous objects.

Family CURTICIIDÆ Walcott and Schuchert, new

Primitive Obolacea with a high, well-defined delthyrium. Interior characters much as in Obolidæ.

Curticia

Family OBOLIDÆ King, 1846 (emend)

Derived, progressive Obolacea with thickened, striated, vertical cardinal areas traversed by pedicle grooves. Muscles and vascular trunks strongly impressed in the valves.

Subfamily OBOLINÆ Dall, 1870 (emend)

Primitive Obolidæ with the pedicle grooves more or less shallow or deeply rounded, but never tending to form a sheath or to com-

pletely restrict the pedicle opening to the ventral valve. The radicle of the Trimerellidæ, by way of the Neobolinæ, appears to be in this subfamily in the thick-shelled Middle Cambrian forms of *Obolus* (s. s.)

Obolus
(*Bröggeria*)
(*Palæobolus*)
(*Fordinia*)
(*Lingulobolus*)
(*Mickwitzella*)
(*Acritis*)
(*Schmidtia*)
(*Westonia*)
Lingulella
(*Leptembolon*)
(*Lingulepis*)
Delgadella

Subfamily ELKANIINÆ Walcott and Schuchert, new

Divergent Obolidæ with posterior or marginal (not central) platforms, to which are attached the central and outside and middle lateral muscles.

Elkania

Subfamily NEOBOLINÆ Walcott and Schuchert, new

Progressive Obolidæ with posterior platforms, to which were probably attached the central and outside and middle lateral muscles. Subfamily apparently progressive from the Obolinæ to the Trimerellidæ, though the platform is posterior and not subcentral as in the Trimerelloids.

Neobolus

Subfamily BICIINÆ Walcott and Schuchert, new

Progressive Obolidæ with the pedicle restricted to the ventral valve and more or less enclosed by a pedicle tube, and with rudimentary articulation. The transgressing stock from the Atremata to the Neotremata (Obolellidæ).

Bicia
Dicellomus

Superfamily KUTORGINACEA Walcott and Schuchert, new

Progressive, thick-shelled, almost calcareous Atrematous-like shells, tending to be transverse and developing rudimentary articulation, more or less rudimentary cardinal areas, pseudodeltidia, and

muscle scars prophetic of the Protremata. Derived out of Rustellacea.

Family KUTORGINIDÆ Schuchert, 1893

Progressive transverse Kutorginacea with rudimentary cardinal areas, great delthyrial opening, rudimentary articulation, and immature pseudodeltidia. Muscle scars prophetic of the Strophomenacea.

Kutorgina

Family SCHUCHERTINIDÆ Walcott, new

Primitive round Kutorginacea with small cardinal areas. Externally like *Obolus,* with an open subtriangular delthyrium which apparently is without a pseudodeltidium. Muscle scars and vascular markings prophetic, through the Billingsellidæ, of the Strophomenacea.

Schuchertina

Order NEOTREMATA Beecher, 1891 (emend)

Derived and specialized inarticulate Brachiopoda (through the Obolidæ of the Atremata), as a rule more phosphatic than calcareous, more or less cone-shaped, with the pedicle emerging during life through a perforation or sheath in the ventral valve, or a triangular, more or less open cleft, or only so in the youngest shelled stage, after which the ventral valve becomes attached by a pedicle to foreign objects. Pedicle cleft in derived forms modified by a listrium. Pseudodeltidia and pseudochilidia as a rule not well developed.

Superfamily SIPHONOTRETACEA Walcott and Schuchert, new

Primitive, thick-shelled, calcareous or corneous, oboloid Neotremata, with the pedicle passing through a ventral sheath, the aperture of which may remain apical and circular in outline, or it may become elongate through resorption by passing anteriorly through the protegulum and umbo of the shell. A listrium is not developed. Dorsal protegulum marginal.

Family OBOLELLIDÆ Walcott and Schuchert, new

Primitive Siphonotretacea with the pedicle emerging through a small circular perforation in the apex of the ventral valve, posterior to the protegulum. Derived out of the Obolidæ.

Obolella
(*Glyptias*)
Botsfordia
Schizopholis
(?) *Quebecia*

Family SIPHONOTRETIDÆ Kutorga, 1848 (emend)

Progressive Siphonotretacea with the circular or elongate pedicle opening at the apex or passing by resorption anteriorly through the protegulum and the umbo of the shell.

Yorkia
Dearbornia
Trematobolus
Schizambon
Siphonotreta
Keyserlingia

Superfamily ACROTRETACEA Schuchert, 1896 (emend)

Progressive Neotremata with corneous or calcareo-corneous shells. The pedicle opening is a simple, circular, more or less conspicuous perforation through the apex of the ventral valve. Dorsal protegulum marginal.

Family ACROTRETIDÆ Schuchert, 1893

Same characters as superfamily.

Subfamily ACROTHELINÆ Walcott and Schuchert, new

Depressed, large Acrotretidæ.

Acrothele
(*Redlichella*)
Discinolepsis

Subfamily ACROTRETINÆ Walcott and Schuchert, new

Small Acrotretidæ with more or less high ventral valves.

Linnarssonella
Acrotreta
Acrothyra
Discinopsis

Superfamily DISCINACEA Waagen, 1885

Derived Neotremata with phosphatic shells, a listrium modifying the pedicle slit, and without pseudodeltidia and false cardinal areas. Dorsal protegulum usually subcentral.

Family DISCINIDÆ Gray, 1840

Discinacea with an open pedicle notch in early life in the posterior margin of the ventral valve, which is closed posteriorly during

neanic growth, leaving a more or less long, narrow slit partially closed by the listrium.

Orbiculoidea

Superfamily CRANIACEA Waagen, 1885

Cemented calcareous specialized Neotremata without pedicle or anal openings at maturity.

Family CRANIIDÆ King, 1846

Craniacea with the pedicle functional probably only during nepionic growth.

Philhedra

Order PROTREMATA Beecher, 1891 (emend)

Progressive (though atrematous Kutorginacea), articulate calcareous Brachiopoda with well-developed cardinal areas. The pedicle opening is restricted to the ventral valve throughout life or during early growth and is often modified and more or less closed by a deltidium. Often there is a chilidum. Brachia unsupported by a calcareous skeleton other than crura.

Superfamily ORTHACEA Walcott and Schuchert, new

Derived, progressive Protemata. Cruralia and rudimentary spondylia (pseudospondylia) free or cemented (through sessility) directly to the valves. Sometimes without deltidia and chilidia. Cardinal process more or less well-developed except in the most primitive genera.

Family BILLINGSELLIDÆ Schuchert, 1893

Primitive Orthacea with an open or more or less closed delthyrium. Cardinal process well developed, rudimentary, or absent. Usually with a clearly defined pseudospondylium, to which the muscles of the ventral valve were attached. Shell structure dense, granular, lamellar, non-fibrous.

Subfamily NISUSIINÆ Walcott and Schuchert, new

Primitive Orthacea with more or less well-developed deltidia and with or without rudimentary chilidia. Spondylia and cruralia rudimentary or small and not supported by septa. Cardinal process rudimentary or absent.

Nisusia

(*Jamesella*)

Protorthis

(*Loperia*)

Subfamily BILLINGSELLINÆ Schuchert, 1893

Primitive Orthacea very much like Nisusiinæ but without true spondylia and cruralia. There is a more or less well-developed cardinal process except in Lower Cambrian forms.

Wimanella
Billingsella
Orusia
Otusia
Wynnia

Subfamily EOORTHINÆ Walcott, new

Derived Orthacea nearly always with large open delthyria; deltidia and chilidia occasionally retained throughout life, but more often only in the younger growth stages. Cardinal process well developed. Shell structure dense, granular, and with punctate lamellæ.

Eoorthis.
Finkelnburgia

Superfamily STROPHOMENACEA Schuchert, 1896

Derived, progressive, terminal Protremata, out of Orthacea (Billingsellidæ). Deltidia and chilidia nearly always well developed. Cardinal process always well developed.

Family STROPHOMENIDÆ King, 1846

Subfamily RAFINESQUINÆ Schuchert, 1893

Strophomenoids having generally a convex ventral and a concave or nearly flat dorsal valve.

Eostrophomena

Superfamily PENTAMERACEA Schuchert, 1896 (emend)

Specialized Protremata with well-developed free or supported spondylia and cruralia. Deltidia and chilidia usually absent.

Family SYNTROPHIIDÆ Schuchert, 1896

Primitive Pentameracea with long, straight cardinal areas.

(?) *Swantonia*
Syntrophia
Huenella
Clarkella

STRUCTURE OF THE SHELL

The classification of the Protrematous genera is so profoundly influenced by the structure of the shell that it was decided to include the following notes:

The general structural characters of the shell of the Ordovician and later brachiopoda have been so fully described by authors that it does not appear to be necessary or desirable to repeat them. The student will find a full description given by Messrs. Hall and Clarke in their "Introduction to the Study of the Brachiopoda" [1892, pp. 150–225].

Some of the more important works that contain data on the structure of the shell are Hancock, "On the Organization of the Brachiopoda" [1859, pp. 791–869]; King, "On Some Characters of *Lingula anatina*" [1873, pp. 1–17]; Carpenter, "On the Intimate Structure of the Shells of Brachiopods" [1853, pp. 23–45]; Davidson, "On the Classification of the Brachiopoda" [1853, pp. 41–136]; and Mickwitz, "Ueber die Brachiopodengattung *Obolus*" [1896].

The greater proportion of the Cambrian brachiopoda is largely corneous or chitinous. These brachiopoda are restricted to the inarticulates, but the inarticulates of the Cambrian do not all possess corneous shells. Dr. Mickwitz has shown [1896, pp. 102–142] that the shells of *Obolus* and its subgenera are essentially the same as those of *Lingula* in composition and structure. In both the shells are composed of successive calcareous and corneous lamellæ that vary in thickness and structure. The calcareous lamellæ are prismatic and penetrated by minute tubules; the corneous lamellæ are compact and imperforate.

Messrs. Hall and Clarke, in speaking of the shells of the articulate brachiopoda, say: "Among the articulate genera, under favorable preservation, there may be distinguished three distinct calcareous shell layers: an inner prismatic or fibrous layer, which constitutes the greater portion of the shell; above this is a thin lamellar layer, and the outer surface of the shell is covered by a tenuous epidermal film or periostracum. When the shell is punctate the tubules open on the inner surface in narrow apertures, whence they widen upwards, abruptly expanding in the lamellar layer, at whose upper margin they terminate. They do not pierce the periostracum." [1892, p. 175.]

Among the calcareous, inarticulate brachiopoda the shell of the Cambrian genus *Obolella* shows a dense, compact, slightly lamellated structure made up of a granular ground-mass pierced by extremely small tubules or pores. The substance of the shell of *Rustella* and

Yorkia is unknown, but from the character of the casts and the fact that the shells of *Micromitra* in the same matrix are preserved, it is probable that it was calcareous. The shells of *Quebecia, Trematobolus,* and *Dearbornia* are also calcareous.

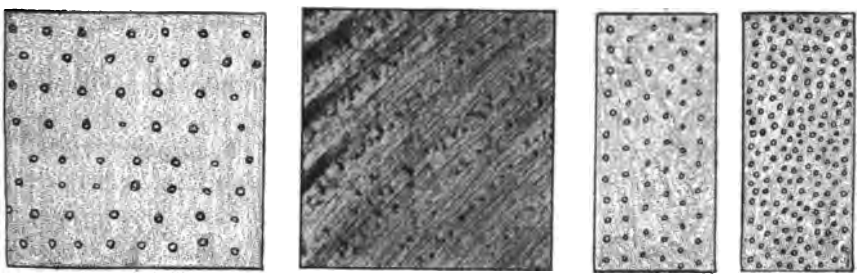
In *Kutorgina* and *Schuchertina,* forms that may be referred to either the Atremata or the Protremata, the shells appear to be calcareous, compact, and without fibrous structure. Messrs. Hall and Clarke, when speaking [1892, p. 174] of the composition of the shell of fossil linguloids, said: "In the group of fossil linguloids, beginning with *Lingula,* passing through *Lingulops* and *Lingulasma* to *Trimerella* and its allies, there is a regular increase in the relative amount of calcareous matter in the shell, so that the *Trimerellas,* which are large and ponderous shells, seem to have wholly lost their corneous matter."

The predominance of corneous or calcareous shell matter does not appear to be of more than generic importance in the classification of the brachiopoda. It is true that the known articulate genera are all calcareous, but it is equally true that among the inarticulate group calcareous shells occur. Alteration, replacement, and removement of original shell substance have changed the shell of so many species that other characters must be depended upon for classification.

MICROSCOPIC STRUCTURE OF THE CAMBRIAN BRACHIOPODA.—In previous work on the Cambrian Brachiopoda, except in the cases above cited, practically no attention has been paid to their microscopic shell structure. The importance of this feature in the classification of later species suggested the possible value of a microscopic study of the earlier forms, and at my request Mr. R. S. Bassler, of the United States National Museum, prepared thin-sections and also assisted in the preparation of the accompanying illustrations and in the preliminary study of the sections.

The preparation of thin-sections of these early brachiopoda is accompanied with difficulties which, together with the lack of sufficiently extensive collections, have undoubtedly prevented previous study along the same line. Specimens suitable for sectioning, especially of the calcareous forms, are not at all common, and when they do occur they are almost invariably buried in the rock, and are so thin that the parting of the enclosing matrix does not leave sufficient shell substance for the preparation of sections. In the present work the specific identity of a shell was first determined by uncovering about one-half the valve, and the other half, still embedded in the matrix, was then used in making the section. The structural features are often restricted to individual lamellæ, and the right zone

for microscopic examination was determined simply by close observation as grinding proceeded. Both vertical and tangential sections were prepared, the former cutting the shell at right angles and the latter cutting the shell in planes more or less parallel to the layers or lamellæ of which it is composed. The most interesting results were obtained from the tangential sections, as the thin shells showed little decided structure in vertical sections.



2 3 4 5

FIG. 2. *Billingsella plicatella* Walcott [1905, p. 240]. Upper Cambrian, Gallatin Valley, Montana.

Diagrammatic sketch of a small portion of a tangential section, × 200. The granular ground-mass, with small pores and tubules 4 or 5 times their own diameter distant from each other, is also typical of other members of the Billingsellidæ.

FIG. 3. *Dalmanella subequata* (Conrad) [1843, p. 333]. Ordovician (Stones River), St. Paul, Minnesota.

Photograph of a tangential section, × 35, showing the fibrous structure and comparatively large pores.

FIG. 4. *Kutorgina cingulata* (Billings) [1861, p. 8]. Lower Cambrian, Swanton, Vermont.

A small portion of the tangential section figured on Plate 12, fig. 4, × 200. The minute structure of this and the following species is essentially the same as that shown in fig. 1, the only difference being the closer arrangement of the pores.

FIG. 5. *Obolus apollinis* Eichwald [1829, p. 274]. Upper Cambrian Obolus sandstone, Esthonia, Russia.

Small portion of tangential section × 200. The minutely porous granular structure is beautifully shown in this species, in which the pores are arranged more closely than in any other observed.

The general resemblance of the Cambrian eoorthoids to certain Ordovician Protremata is so striking and the lines of descent so suggestive that particular attention was devoted to this group, and the examination brought out the fact that this apparent relationship disappears when the shell structure of the two groups is compared.

Sections of the shells of members of the Billingsellidæ, of which

figure 2 is typical, all show a lamellar structure with indications of more or less numerous and scattered, very minute pores or tubules passing without interruption through one lamella. In some sections the spots indicating the tubules are arranged in rows radiating from the beak of the shell to the margins, but no other regular arrangement can be seen. The great mass of the shell is made up of a compact, finely granular base with dark spots and occasional minute crystals of calcite—a ground-mass which, under the microscope, appears very much like that of a fine argillaceous shale.

The Ordovician Protremata have a clearer, more crystalline aspect or color than the Cambrian Billingsellidæ—a difference which probably indicates either a purer lime composition for the former or more probably a higher percentage of calcium phosphate for the latter. In chemical aspect the shells of the Billingsellidæ appear to resemble those of the Atremata and Neotremata more closely than do the Orthidæ. Analyses of the respective shells would be necessary to prove these relations, but to note them is interesting in view of the possible derivation of the Billingsellidæ from the Atremata.

In the Cambrian articulate genera, with the possible exception of *Syntrophia* and *Huenella,* there is an entire absence of the minute, fibrous structure so characteristic of most, if not all, orthoids. But these two representatives of the Pentameracea greatly resemble each other. Thus sections of the shell of *Huenella abnormis* (Walcott) of the Upper Cambrian (see pl. 12, fig. 9) and *Syntrophia lateralis* (Whitfield) of the Lower Ordovician (see pl. 12, fig. 7) show the same radial arrangement of the pores seen in the Billingsellidæ, but the shell structure is fibrous and the rows are coincident in direction with the fibers. Upon closer study this apparent fibrous structure can be resolved into more or less parallel bands or walls of shell substance separating rows of closely arranged, rectangular, pore-like spaces. These spaces may be seen distinctly in thick sections, but when the section is made sufficiently thin to give a clear image under very high power, the pore structure disappears.

Sections of the linguloid genera were also prepared and studied, but the thinness of the shells and their phosphatic character prevented very satisfactory results. The irregular large tubules mentioned by Dr. Mickwitz [1896] are beautifully shown in the sections of *Obolus apollinis* before me. Some of the tubules penetrate several lamellæ of the shell and suggest the tubules of some of the orthoids. (See figures 11 and 12, pl. 12.) The same general structure, with the exception of the larger tubules, appears to be characteristic of all of

the corneous shells of the Atremata and Neotremata, and, as far as known to me, all of the Cambrian corneous shells are of this type.

The figures on the accompanying plate, with the exception of figures 11 and 12, are from photographs which have not been retouched. Unfortunately higher magnifications could not be used without a loss of clearness; but, even at the present magnification, these views show a decided difference in structure.

In conclusion, it appears that the Cambrian Billingsellidæ are further removed from the Ordovician and later Protremata than hitherto suspected, the microscopic shell structure in the former being of granular material pierced by small pores and in the latter of fibrous material. On the other hand, the microscopic structure of the Cambrian and later Pentameracea is so similar that an unbroken line of descent is indicated.

TERMINOLOGY RELATING TO THE SHELL

The definitions given in the following pages are largely those of Schuchert [1897, pp. 73–75], with the exception of the muscle scars of the inarticulate brachiopods. For the Atremata and Neotremata the terminology proposed by Professor William King [1873, pp. 5, 6] is adopted, and for the Protremata that used by Messrs. Hall and Clarke [1892, pp. 183–188] and given under the terminology of Schuchert. [1897, pp. 73–77]. I agree with Messrs. Hall and Clarke that Professor King's terminology has claims for its adoption, owing to its simplicity. Dr. F. Blochmann has proposed [1900, p. 108] a set of terms for the muscles of the inarticulate brachiopods that has much to commend it. The terminology of Mr. Albany Hancock [1859, p. 800] has been extensively used by authors. The numbers below correspond to the numbers given the terminology of King, Schuchert, and Blochmann.

HANCOCK, 1859

Inarticulates	*Articulates*
1. Anterior occlusors.	1. Anterior occlusors.
2. Posterior occlusors.	2. Posterior occlusors.
3. Divaricator.	3. Accessory divaricators.
4. Central adjustors.	4. } Ventral adjustors.
5. External adjustors.	5. }
6. Posterior adjustors.	6. Dorsal adjustors.
7. Peduncular.	7. Peduncular.

KING, 1873

1. Anterior laterals.
2. Centrals.
3. Umbonal.
4. Transmedians.
5. Outside laterals.
6. Middle laterals.

SCHUCHERT, 1897

1. Retractors.
2. Adductors.
3. Pedicle.
4. Rotators.
5. Protractors (externals).
6. Protractors (middles).
7. Diductors.

BLOCHMANN, 1900

1. Lateralis.
2. Occlusor anterior.
3. Occlusor posterior.
4. Obliquus internus.
5. Obliquus externus.
6. Obliquus medius.

DEFINITIONS

ADDUCTOR MUSCLES.—(See Central muscles.) The term adductor is used for the central muscles of the Protremata.

ANTERIOR LATERAL (RETRACTOR) MUSCLES.—In the Atremata these extend from the outer lateral margins of the visceral area in the ventral valve to its anterior extremity in the dorsal valve and serve to readjust the dorsal shell.

ANTERIOR REGION.—That portion of the shell in front of the transverse axis and opposite the pedicle opening.

APEX.—The place of initial shell growth. It may be the most posterior portion of the valve or it may be situated near the transverse axis.

APICAL CALLOSITY.—The thickened boss at the inner side of the apex of the ventral valve of *Acrotreta* and other Neotrematous genera through which the pedicle tube or foramen passes.

AREA.—See Cardinal area.

ARTICULATE BRACHIOPODA.—In the orders Protremata and Telotremata the valves articulate by means of teeth and sockets. In some Atremata rudimentary articulation is also developed.

ATREMATA.—Primitive inarticulate, calcareo-phosphatic or corneous brachiopods with the pedicle emerging more or less freely between the two valves. (For a more detailed description see page 142.)

BRACHIA.—The fleshy, coiled or spiral, ciliated appendages of brachiopods serving in water circulation and respiration.

BRACHIOCŒLE.—All of the anterior half of the valves outside of the anterior portion of the parietal band. (After King.)

CARDINAL AREA.—A more or less well-developed triangular area on each side of the delthyrium, distinctly set off from the general surface of the shell. It is best developed on the ventral valve of articulate brachiopods, but is also present on the dorsal valve, and generally in a rudimentary condition in many inarticulate species. When the area is rudimentary it is often called a false or pseudo-area. The area of some of the inarticulate genera is frequently divided by a line between the delthyrium and the outer margin. In such areas the line is called the flexure line, owing to the slight interruption in the striæ of growth, and the spaces separated by the flexure line are called the inner and outer lateral spaces of the area. (See Deltidium and Foramen.)

CARDINAL EXTREMITIES.—The terminations of the hinge line.

CARDINAL MUSCLE SCAR.—A large scar within which the posterior and anterior lateral and transmedian muscle scars were attached.

CARDINAL PROCESS.—A variously modified apophysis, situated posteriorly at the center of the hinge of the dorsal valve in articulate brachiopoda. To it are attached the diductor muscles, which by their contraction serve to open the valves anteriorly.

CARDINAL SLOPES.—The inclined surfaces extending from the umbonal slopes to the hinge margins.

CENTRAL (ADDUCTOR) MUSCLES.—In the Protremata and Telotremata these muscles have their ventral insertion one on either side of the central axis, between the diductors. In passing to the dorsal valve they divide into four and produce in that shell the two pairs of principal scars known as the anterior and posterior centrals. By contraction these muscles close the shell. In the Neotremata they are the essential muscles, the anterior centrals closing the valves, while the posterior pair serves to open the valves. In the Atremata there is a simple pair of centrals placed near the anterior extremity of the visceral area.

CHILIDIUM.—A dorsal plate, in appearance similar to the deltidium, covering the exterior portion of the cardinal process in many Protremata. Its development does not begin until early neanic or later growth and it is probably secreted by the dorsal mantle lobe. In the Atremata and Neotremata there is a similar plate continuous with the dorsal cardinal region of the shell, and it is named the pseudochilidium.

CRURA.—Processes on the dorsal hinge plate of the Telotremata and some Protremata, to which are attached the fleshy brachia and brachidia. These usually form the inner walls of the dental sockets and may be supported by septal plates.

CRURALIUM.—The dorsal equivalent of the ventral spondylium.

DELTHYRIUM.—The triangular aperture transecting medially the ventral cardinal area, or the posterior surface from the apex to the posterior margin of the ventral valve, through some portion of which the pedicle passes. It has also been termed the *fissure* or *foramen*. The delthyrium may or may not be closed either by a calcareous deltidium or a phosphatic pseudodeltidium.

DELTIDIUM.—A plate more or less continuous with the cardinal margin on the ventral valve covering the delthyrium in Atremata, Neotremata, and Protremata. When present in inarticulate brachiopods it is called the pseudodeltidium, and in the Protremata, where it is always more calcareous, thicker, and more sharply defined, the deltidium and pseudochilidium.

DENTAL PLATES.—Vertical plates supporting the teeth of the ventral valve in articulate brachiopods.

DENTAL SOCKETS.—Excavations in the dorsal cardinal margin of articulate brachiopods in which the teeth of the ventral valve articulate. The inner wall of the socket is elevated and forms the base of the crural plate.

DIDUCTOR MUSCLES.—In the Protremata and Telotremata the principal pair of diductor muscles has the larger end attached to the ventral valve near the anterior edge of the visceral area, while the other end has its insertion on the anterior portion of the cardinal process. By contraction these muscles open the valves.

DORSAL VALVE.—Usually the smaller and imperforate valve and the one to which the brachia are always attached. *Brachial, hæmal, socket,* and *entering* valves are other terms more rarely employed.

EPHEBIC.—Designating the mature shell.

FALSE AREA.—See Cardinal area.

FLEXURE LINE.—See Cardinal area.

FORAMEN.—A small circular passage through the deltidium, either below or at the apex of the ventral valve. Sometimes the foramen encroaches by pedicle abrasion upon the umbo of the ventral valve.

FORAMINAL TUBE.—The pedicle opening through the ventral valve of Neotrematous genera.

GENITAL MARKINGS.—Radial markings or pits within the posterior portion of the visceral space, indicating the position and extent of the genitals.

GERONTIC.—Designating old age. It is indicated in the ontogeny of many species of brachiopods by extreme thickness of the valves, obesity, or by numerous, crowded growth lines near the anterior margin—a condition which sometimes produces truncation and absence of striæ at the margin.

HEART-SHAPED CAVITY.—Central depressed portion of visceral area (Mickwitz).

HINGE LINE.—The line along which articulation takes place; also sometimes developed among inarticulate brachiopoda.

INARTICULATE BRACHIOPODA.—In the orders Atremata and Neotremata the valves do not, as a rule, articulate by means of teeth and sockets, as is the case in the articulate orders Protremata and Telotremata.

LATERAL AREAS.—That portion of the shell on each side of the longitudinal axis.

LISTRIUM.—In some Neotremata a plate closing the progressive track of the pedicle opening or pedicle cleft, posterior to the apex of the ventral valve.

LONGITUDINAL AXIS.—A median line through the shell from the beak to the anterior margin.

MEDIAN SEPTUM.—An internal vertical plate commonly developed along the longitudinal axis and between the muscles of the ventral valve. Sometimes there is also a dorsal median septum. Lateral septa are rarely developed.

MIDDLE LATERAL MUSCLE SCAR.—See Outside lateral.

NEANIC.—Designating youthfulness, or the stage in which specific characters begin to develop.

NEOTREMATA.—Circular or oval, more or less cone-shaped, inarticulate calcareo-phosphatic brachiopods with the pedicle opening restricted throughout life to the ventral valve. (For a more detailed description see page 145.)

NEPIONIC.—Designating the smooth shell stage succeeding the protegulum.

OUTSIDE AND MIDDLE LATERAL (PROTRACTOR) MUSCLES.—In the Obolidæ one pair has the ventral ends fastened at the anterior extremity of the visceral area, extending backward and inserted near the lateral margin of the dorsal valve, outside the transmedians. A second pair originates just behind the centrals of the ventral valve and is inserted posterior to the first pair. These muscles draw the dorsal valve forward.

PARIETAL BAND.—The point of attachment of the muscular wall surrounding the visceral area.

PEDICLE.—The flexible muscular organ of the ventral valve by means of which brachiopods may be attached to extraneous objects.

PEDICLE FURROW.—The external furrow adjoining the foramen or pedicle opening in certain Neotrematous genera.

PEDICLE GROOVE.—The median groove on the cardinal areas of the valves formed by the pedicle extending through the posterior margin of the valves when they were closed.

PEDICLE MUSCLES.—In the Protremata and Telotremata one pair originates on the ventral valve at points just outside and behind the diductors, and another on the dorsal valve behind the posterior centrals, while the opposite ends of both are attached to the pedicle. Besides these, there is an unpaired muscle lying at the base of the pedicle, attaching it closely to the ventral valve.

PEDICLE OPENING.—See Delthyrium.

PEDICLE TUBE.—See Foraminal tube.

PLATFORM.—An internal median thickening of the shell elevating the muscles. Seen in certain families of the Atremata and more rarely in the Neotremata. (See Spondylium.)

PLEUROCŒLES.—Areas between the parietal band and the outer postero-lateral margins. (After King.)

POSTERIOR REGION.—That portion of the shell back of the transverse axis and toward the beak, or apex.

PROTEGULUM.—The initial shell of brachiopoda. It is smooth and of microscopic size, in outline being semicircular or arcuate and without cardinal areas. Rarely seen in adult shells.

PROTRACTOR MUSCLES.—See Outside and middle lateral muscles.

PROTREMATA.—Articulate, calcareous brachiopods, with the pedicle opening restricted to the ventral valve throughout life or during early growth. Pedicle aperture modified by the deltidium. Brachia unsupported by a calcareous skeleton, but nearly always by a more or less long crura. (For a more detailed description, see page 147.)

PSEUDO-AREA.—See Cardinal area.

PSEUDOCHILIDIUM.—See Chilidium.

PSEUDOCRURALIUM.—Dorsal equivalent of pseudospondylium.

PSEUDODELTIDIUM.—The convex medial portion continuous with the ventral cardinal areas in Atremata and Neotremata. (See Deltidium.)

PSEUDO-PEDICLE GROOVE.—See Pedicle groove.

PSEUDOSPONDYLIUM.—See Spondylium.

RETRACTOR MUSCLES.—See Anterior lateral muscles.

SEPTAL PLATES.—Plates supporting the crural processes; also known as *crural plates*.

SESSILE SPONDYLIUM = Pseudospondylium.

SPLANCHNOCŒLE.—The area within the parietal band. (After King.)

SPONDYLIUM.—A plate in some articulate brachiopoda, mainly the Pentameracea, formed by the union of converging dental plates, to the upper surface of which are attached the adductor, diductor, and pedicle muscles. The spondylium may rest upon the ventral valve or may be supported by a median septum. The spondylium appears to be first indicated in the articulates by a thickening of the shell of the ventral valve beneath the umbonal region so as to form an area upon which all the muscles of the valve have their points of attachment. In *Billingsella* this is beautifully illustrated by *B. exporecta* and *B. plicatella.* In its development the spondylium is foreshadowed in the Atremata by the so-called platform of *Fordinia* and the still more primitive form in *Obolus.* For the purpose of reference, the rudimentary spondylia attached directly to the inner surface of the valve, as in *Billingsella,* may be called pseudospondylia (sessile spondylia, Ulrich), and those free or supported by a septum or septa, spondylia. In the Cambrian Atremata the homologous equivalent has been known as the platform. In *Obolus,* etc., there is sometimes developed in the dorsal valve a plate similar in appearance to the spondylium, but different in origin and known as the cruralium.

TEETH.—Two processes of the ventral valve of articulate brachiopoda, serving for articulation.

TRANSMEDIAN (ROTATOR) MUSCLES.—In Obolacea these are situated posteriorly just in advance of the umbonal muscle, two on one side and one on the other. By their contraction the dorsal valve turns alternately first in one direction and then in the other.

TRANSVERSE AXIS.—A line through the shell from right to left, midway between the beak and anterior region. (See Longitudinal axis.)

TRAPEZOIDAL AREA.—The area on each side of the heart-shaped cavity in *Obolus* in which the outside and middle lateral scars and central muscle scars are attached.

UMBO.—The elevated or prominent portion of the valve anterior to the apex.

UMBONAL CAVITY.—The hollow space in the interior of the shell beneath the umbo.

UMBONAL MUSCLE.—A single muscle situated in the umbonal region of most Atremata. By its contraction the valves are opened anteriorly. In *Obolus* this muscle divides toward the ventral valve.

UMBONAL SLOPES.—The inclined surfaces about the umbo and opposite the cardinal slopes.

VENTRAL VALVE.—Usually the larger valve situated on the ventral side of the animal. Among articulate brachiopoda the valve is usu-

ally easily distinguished by the presence of a delthyrium or pedicle opening through which the pedicle is protruded. In many Atrematous genera the ventral valve is not readily distinguished. When the shell is cemented to foreign bodies it is always by the ventral valve. It is usually the larger and deeper of the two valves. *Pedicle, larger, dental, neural,* and *receiving* valves are synonymous terms.

VASCULAR (PALLIAL) SINUSES.—Two convergent or divergent primary sinuses of the circulatory system, traversing the mantle and originating in the posterior medial region. They usually have numerous secondary (lateral and peripheral) branches and both often leave impressions in the shell.

VISCERAL AREA.—The posterior region of the interior of the valves between the pallial sinuses; in general, the immediate area of the median muscle tracks.

VISCERAL CAVITY = Visceral area.

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DESCRIPTION OF PLATE 12

Billingsella coloradoensis (Shumard) [1860, p. 627]:

FIG. 1. Photograph of horizontal thin-section enlarged fifty diameters. This shows the characteristic granular ground-mass of the Cambrian Billingsellidæ. Upper Cambrian, Morgan Creek, Burnet County, Texas.

Nisusia festinata (Billings) [1861, p. 10]:

FIG. 2. Photograph of horizontal thin-section enlarged fifty diameters. This section shows a granular ground-mass in which there are faint indications of small pores or tubulæ which may be seen with a high power. Lower Cambrian, 2 miles east of Swanton, Vermont.

Eoorthis remnicha (N. H. Winchell) [1886, p. 317]:

FIG. 3. Photograph of horizontal thin-section enlarged fifty diameters. This section shows the same type of ground-mass as that illustrated by fig. 2. Upper Cambrian, Cold Creek Canyon, Burnet County, Texas.

Kutorgina cingulata (Billings) [1861, p. 8]:

FIG. 4. Photograph of horizontal thin-section showing granular shell substance. There are few slight indications of pores. Lower Cambrian, Swanton, Vermont.

Dalmanella multisecta (Meek) [1873, p. 112]:

FIG. 5. Horizontal thin-section enlarged fifty diameters. This shows the fibrous structure of the shell penetrated by numerous fine tubules. Ordovician Eden formation, Cincinnati, Ohio.

Dalmanella parva (de Verneuil) [1845, p. 188]:

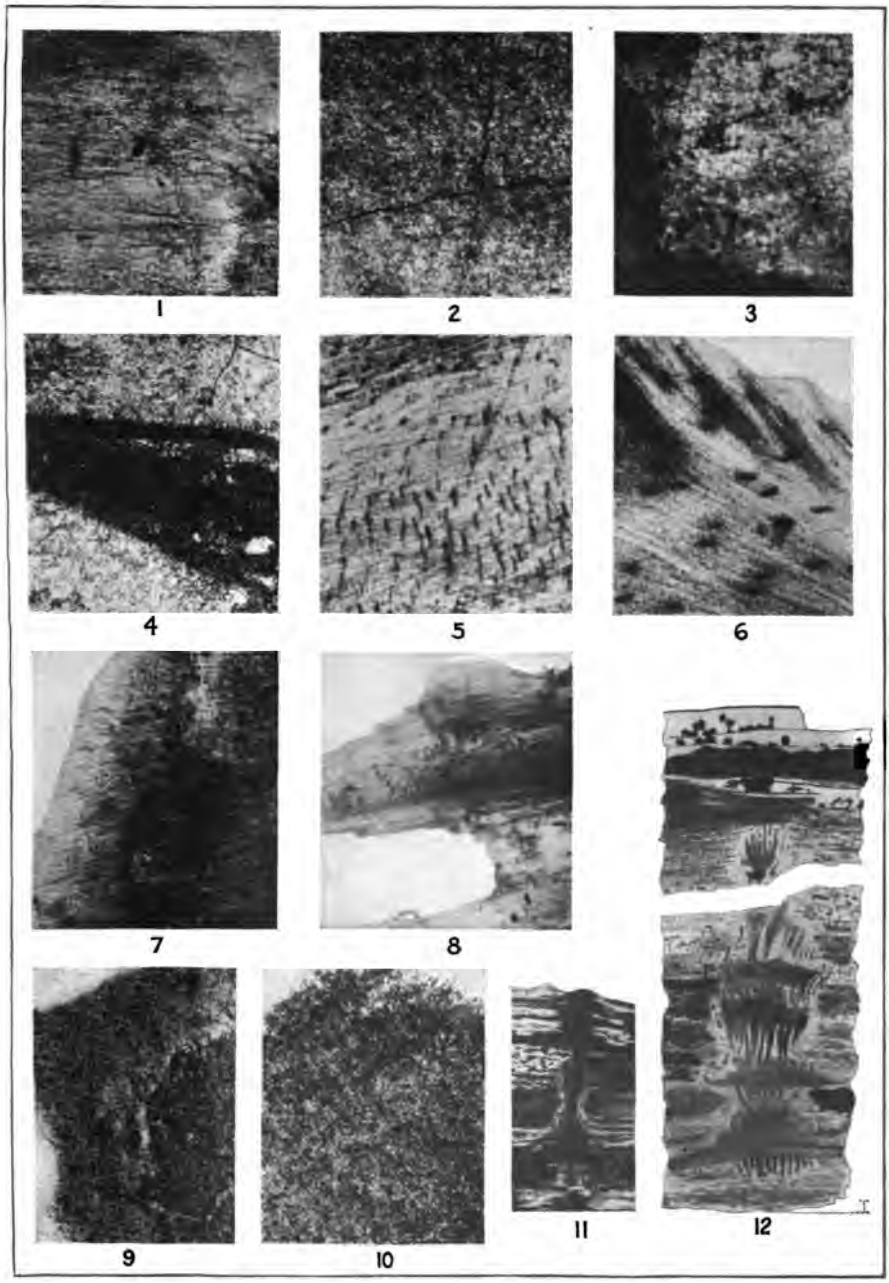
FIG. 6. Horizontal thin-section showing fibrous structure; also section of the tubules that penetrate through the shell. Middle Ordovician of Russia.

Syntrophia lateralis (Whitfield) [1886, p. 303]:

FIG. 7. Horizontal thin-section enlarged fifty diameters, showing the arrangement of the pores in lines that radiate from the apex toward the margin. Lower Ordovician Cassin limestone, Fort Cassin, Vermont.

Plectorthis plicatella (Hall) [1847, p. 122]:

FIG. 8. Horizontal thin-section enlarged fifty diameters. This section shows the fibrous structure so characteristic of the Ordovician orthoids. Ordovician Lorraine shaly limestones, Cincinnati, Ohio.



MICROPHOTOGRAPHS OF ROCK SECTIONS

Huenella abnormis (Walcott) [1905, p. 289]:

FIG. 9. Horizontal thin-section enlarged fifty diameters. The pores in this genus are smaller than in *Syntrophia,* but their arrangement is essentially the same and shows the line effect characteristic of the Pentameracea. Upper Cambrian, Gallatin Valley, Montana.

Obolella crassa (Hall) [1847, p. 290]:

FIG. 10. Horizontal thin-section enlarged fifty diameters. This shows the fine granular ground-mass, with an indication in the upper left side of the section that a surface ornamentation has been cut across. Lower Cambrian, Bic, Canada.

Obolus apollinis Eichwald [1829, p. 274]:

FIGS. 11 and 12. Transverse, vertical thin-section enlarged so to to show the lamellæ and the presence of a large tubule that appears to have more or less imperfectly penetrated through the shell. Upper Cambrian Obolus sandstone, Russia.

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